REPORT

ON

SOLID WASTES MANAGEMENT

PREPARED FOR
DEPARTMENT OF COMMERCE AND DEVELOPMENT
THE COMMONWEALTH OF MASSACHUSETTS
AND
GOVERNOR'S ADVISORY COMMITTEE ON
SCIENCE AND TECHNOLOGY
THE COMMONWEALTH OF MASSACHUSETTS
BY

JOHN J. COCHRANE AND ALVIN S. GOODMAN

BOSTON, MASSACHUSETTS
JULY, 1967

HON. JOHN A. VOLPE
Governor

HON. THEODORE W. SCHULENBERG
Commissioner

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May 31, 1968

HIS EXCELLENCY JOHN A. VOLPE
GOVERNOR OF MASSACHUSETTS
STATE HOUSE
BOSTON, MASSACHUSETTS

Dear Governor Volpe:

On behalf of the Governor's Advisory Committee on Science and Technology, I have the pleasure of transmitting to you a revised copy of our Waste Management Report.

The over-all conclusions reached in the report are that modern technology, if properly applied, is adequate to deal with the solid waste disposal problem; and that the present and in some cases intolerable situation has arisen from difficulties which are organizational and functional in nature.

Of the several recommendations to remedy this situation, the principal one is to designate the State Department of Public Health as the main state agency with legal and administrative powers related to Solid Waste Management.

While the Committee generally endorses the report, it feels that it cannot endorse recommendations which relate to specific functions of departments of the state government, such activities being beyond the scope of its mission.

We do, however, endorse the idea behind this particular recommendation, namely that the ultimate regulation of not only solid waste, but all waste disposal systems should be the responsibility of a single agency which is equipped and qualified to develop and maintain performance criteria in public health practices.

The reason behind this recommendation is clear. Obviously, it is possible to dispose of garbage by throwing it in a dump or dispose of raw sewage by dumping it in a river. The point here is that both practices constitute public health hazards. For this reason it is necessary for a regulatory agency to insure that any and all procedures are carried out properly. Furthermore, waste management must be considered as an integrated whole. Otherwise, there is the danger that in trying to dispose of solid waste, for instance by incineration or land fill under improper conditions, excessive atmospheric or natural water pollution might ensue.

In closing, I would like to say that it has been my pleasure to serve both you and the committee in preparing this report.

Sincerely yours,

LEON E. BEGHIAN, *Chairman*

Committee on Waste Management

Honorable Theodore W. Schulenberg, *Commissioner,*
Department of Commerce and Development
Commonwealth of Massachusetts
State House
Boston, Massachusetts

—and—

Dean Martin W. Essigmann, *Chairman*
Dr. Leon E. Beghian, *Subcommittee Chairman for Solid Wastes Management*
Governor's Advisory Committee on Science and Technology
Commonwealth of Massachusetts
State House
Boston. Massachusetts

Gentlemen:

We are pleased to submit our report on solid wastes management, which was authorized by our agreements with the Department dated March 1, 1967 and June 28, 1967.

Our major objectives in this report are to delineate recommended improvements in the technical, legal, and administrative aspects of solid wastes management in the Commonwealth, and to suggest additional studies of the problems that should be undertaken. In our recommendations concerning legislation and organization, we have commented on desirable aims rather than on the specific language of laws and administrative directives.

We have devoted a portion of the report to a description of solid wastes technology, and have reviewed some research and development programs, in order to provide a foundation for our evaluations of the current status of the field and our prognosis of future technological improvements and innovations. Compendiums of collection and disposal practices are available, notably those prepared by the American Public Works Association.

There is no single optimum method for handling solid wastes problems in the Commonwealth. The most effective solution for one location, whether it be a town or a large region, may be quite different from that for another. The best plan in each instance, considering the often conflicting requirements of construction feasibility, public health, economics and other factors, should be recommended by qualified professional engineers after comprehensive studies.

Existing technology now permits a satisfactory plan to be formulated for solid wastes management anywhere in the Commonwealth. In our opinion, there is no excuse for inaction based upon some hope that a major breakthrough will result in the techniques for handling solid wastes. We do not suggest that research cannot have fruitful results; rather, we judge that, in the solid wastes field, the development of better methods will be progressive rather than of a startling nature.

A recent study by others completed for the Boston area recommended a capital expenditure of 84 million dollars within three years. We estimate that investments totaling on the order of 200 million dollars within the next 5 to 10 years would be required to place the Commonwealth in a satisfactory

position with respect to solid waste disposal. Annual expenses including interest and depreciation of facilities, operation and maintenance, and administration would be over 25 million dollars for collection and disposal of solid wastes.

Engineering studies for definitive municipal planning reports, and recommendations for capital improvements (not including design) for specific areas, are expected to cost about 2 to 3 million dollars and should be completed as soon as possible. In addition, we believe that about 250 thousand dollars a year, about one percent of the annual costs, would be a reasonable continuing level of expenditure within the Commonwealth for the next several years for broad-based studies of technology and management practices. A "solid waste disposal planning project" for a state survey will be initiated by the Massachusetts Department of Public Health when it receives legislative approval of State funds to match those provided by a U. S. Public Health Service Grant. A total budget of only $60,000 per year for a three year period for the project may be compared with our much higher suggested level of planning effort for the Commonwealth.

Perhaps the most obvious manifestation of poor waste management practice in the Commonwealth is the continued operation of open dumps. Legislation should be enacted to force the conversion of such dumps to sanitary landfills.

Our other more important recommendations and comments for implementation of solid wastes programs have been placed in a section immediately following this letter of transmittal. For an adequate foundation for these recommendations, the reader is referred to the main report.

Respectfully submitted,

John J. Cochrane, PhD, PE and Alvin S. Goodman, PhD, PE

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State Agencies

The Department of Public Health (DPH) is the principal State agency with legal, administrative and coordinative functions related to solid wastes management. Additional qualified personnel and additional legal authority are basic prerequisites for adequate performance by the DPH. The following is a list of both existing and expanded functions recommended for the DPH:

1. Survey present solid waste collection and disposal practices in the Commonwealth.
2. Prepare state-wide plans for overall regulation and control of solid waste disposal practices.
3. Approve all refuse disposal sites, including landfill sites; all refuse disposal works; and all transfer stations and long-haul transportation schemes for solid wastes.
4. Regularly inspect solid waste disposal facilities for proper function.
5. Bring administrative and legal pressures to bear on localities (individual municipalities and regions, as appropriate) that fail to submit adequate plans for solid waste disposal for approval, and that fail to make corrections requested by DPH arising from its approval and inspection functions.
6. Coordinate Federal and State planning and construction grant programs.
7. Issue design, operation and management manuals, and provide guidance concerning technical improvements and innovations for handling solid wastes, based upon a comprehensive effort to keep abreast of ongoing and potential research and development studies by government agencies, educational institutions, and private industry.
8. Arrange training programs for technicians, operators and second-level administrators of solid waste programs, and coordinate training programs with the U. S. Public Health Service and universities for technical planning personnel and first-level administrators.
9. Institute a capability for planning and improving collection systems and procedures in the Commonwealth.
10. Maintain a list of qualified consulting engineers who can be hired by localities for definitive planning and design of disposal systems, and for studies of high technical content for collection systems.
11. Engage in a public information program to make legislature members, city officials, and the public aware of the problems and solutions for solid wastes management.

Other State agencies now, or potentially, involved in solid wastes activities include the Department of Natural Resources (DNR), the Department of Commerce and Development (DCD), and the Department of Public Works (DPW).

The DNR now has authority, with the DPH, to regulate removal, filling and dredging of materials adjacent to inland waters and coastal waters. The DNR and other State agencies should have review functions for disposal sites and other aspects of solid wastes when indicated by their roles in such fields as conservation and water quality control. The DPH should be required to request such review from the DNR and/or other State agency when appropriate. In the event of conflict between conclusions of the DPH and other agencies means should be sought to resolve such conflicts expeditiously (e. g., by retention of consultants for technical advice).

The DCD is the agency responsible for State administrative functions for Federal grant programs related to solid wastes projects of the Department of Housing and Urban Development. It also arranges for technical studies of solid wastes sponsored by the Governor's Advisory Committee on Science and Technology. The extent of study work should be enlarged, as discussed below.

The DPW would construct and operate incinerators, under a bill placed before the legislature,

but not passed. The DPH should retain its recommended authority with respect to design and functioning of plants, whether the construction is by a State agency or a lower governmental organization.

Regional and Local Organizations

Appropriate groupings of communities should be sought for the management of solid waste disposal. The DPH should actively encourage the formation of such groupings, using the recommended regulatory powers and financial pressures if available.

Under pending legislation, the Commonwealth would share the cost of solid waste disposal projects constructed by regional solid wastes disposal districts. We believe that State funds should have higher priority, at the present time, for planning rather than for construction. If it is desired to provide additional subsidies, support may be considered for operation and maintenance after communities have shown good faith by investing in construction. Although construction grant programs have been proposed for the Federal government, substantial assistance may be years away; State programs should not be delayed on the basis of such hypothetical Federal assistance.

A limited number of planning grants are available for localities for solid waste planning and for the acquisition of land under certain circumstances, under Federal programs. A need appears to exist for additional State assistance for both preliminary and definitive planning of projects.

Before each regional facility is constructed, a full analysis should be made of the economics and other aspects of regional operation as compared with individual community operation. An adequate study should also be made to compare the proposed facility with alternative means of disposal. Regional planning reports often appear to be deficient in treating these two subjects.

In a regional plan, adequate response of communities is needed in order to achieve the economies of large-scale operations of disposal facilities. This condition is not assured under an optional membership arrangement for municipalities. Financial incentives, coupled with regulatory powers, as recommended above, would likely provide the influences for adequate regional organization.

In general, the collection function should remain with the individual municipality. Because of the much higher cost of collection and transportation of wastes, as compared to the cost of waste disposal, it may often be more economical to build a municipal disposal installation rather than to join a regional plant.

The recent report by the Metropolitan Area Planning Council recommends a plan of solid waste disposal facilities serving the Greater Boston area. The report makes a good case for regional development, but it does not make as effective a presentation for its recommendation that construction and operation of all regional facilities in the Boston metropolitan area should be by a single agency, the Metropolitan District Commission. If, because of political considerations, communities are unable to form a number of districts, the writers of this report agree that a single entity is a suitable solution.

The establishment of procedures for waste management planning, construction and operation of waste disposal facilities should be the responsibility of regional agencies and individual towns and cities (or a State agency such as the DPW if regional and municipal organizations are unable to perform), with approval and monitoring functions by the DPH. Major problems are an effective legal structure and an equitable arrangement for cost sharing for communities. Operators and other technicians should be properly trained before beginning operation. For community support, and as an educational activity, citizen information programs should be established.

The following is an outline of procedures for a typical program:

1. An experienced and reputable sanitary engineering firm should be hired to develop a report for the proposed project.
2. The report should be officially accepted, and a resolution should be made to construct the facilities recommended by the report.
3. The engineering firm should be authorized to submit the report to the DPH for review and acceptance.
4. Engineering services should be retained to prepare construction plans, specifications and construction documents, and to supervise construction.
5. Any necessary legislation and a financing program should be completed to enable the project to proceed.
6. A construction contract should be let and the project should be completed.
7. The public works organization should be expanded if necessary to establish proper administrative and technical direction, and competent operation and maintainance personnel should be hired.

Research and Development And Special Studies

Responsibility for basic research and development for solid wastes management, with potential widespread application to the Nation's problems, has been assumed by the Federal government. Most of this work is administered by the National Center for Urban and Industrial Health (formerly the Office of Solid Wastes) of the U. S. Public Health Service, Department of Health, Education, and Welfare. This agency also provides matching grants for states to make comprehensive surveys of their solid wastes problems. The DPH has received one of these grants but has not been able to proceed because the Commonwealth's share has not yet been authorized by the legislature. This situation should be corrected at the earliest possible time.

The Governor's Advisory Committee on Science and Technology has devoted much of its effort to environmental problems. It should make its support available to State agencies, particularly the Department of Public Health, in the solution of problems of solid wastes and pollution. To this end, it should consider the advisability of establishing an Environmental Pollution Advisory Board on solid wastes and pollution problems, augmented by technical specialists from state and local agencies and persons from non-governmental entities. This subcommittee could serve as a review board for GACSAT on technical studies which it sponsors, and could periodically evaluate progress by the DPH and other agencies of the Commonwealth in solving the problems of solid wastes and pollution. For effective functioning, the members should serve as individuals in a strictly technical capacity rather than as representatives of the interests which employ them.

It is appropriate for GACSAT to select and sponsor, with the general advice of the DPH, the particular studies of high technical content related to the specific problems of the Commonwealth, which the DPH is unable to do because of insufficient personnel.

Studies may be done by extramural activities of faculty members, state agencies, consulting engineers, engineering planners, and industrial research companies. Some of the important study areas and tasks for the immediate future are the following:

1. Provide for GACSAT representation at meetings, conferences and hearings on state solid waste management matters.
2. Periodic reports evaluating current research from meeting attendance, contacts with researchers, technical journals, etc.
3. Definition of air-water-land environment complex for Massachusetts and implications with respect to solid wastes management.
4. Definitive study of each of a group of representative communities to determine the actual costs of collection and disposal to the taxpayer.
5. Study of potential of improved solid waste collection practices using case histories.
6. Engineering study, including practical aspects and economics, of marketability for waste heat from incinerator operations. This study should also consider the feasibility of incorporating waste heat utilization in a multi-purpose complex for solid waste disposal, waste water treatment, and water treatment.
7. Estimate of quantity and potential value of land that could be created in Boston Harbor and other coastal locations by sanitary landfill operations. Such a study would have to include ecological effects, littoral currents, etc.
8. State wide inventory of sites such as quarries, gravel pits, swamps, etc., that could be utilized for landfill with refuse including an analysis of the potential of using long-haul techniques such as railroad operations. Site selection should include consultations with appropriate agencies such as the Water Resources Commission to determine its overall impact on the environment.
9. Evaluation of desirable levels of financial support for state solid waste administration and operations including a discussion of personnel requirements.
10. Definitive study of a regional plan including overall operations and operations as they affect individual communities with emphasis on benefit-cost evaluations.
11. A study of potential value of salvageable products of industry and studies of possible restrictions on disposable containers for consumer products.
12. A comparative evaluation of each function in a solid waste system performed by private contractor vs. municipal operation. This would include collection, treatment and disposal. Economic, political and social aspects would be considered.

Additional Recommendations

A number of recommendations concerning the technical aspects of designs for solid wastes collection and disposal are made throughout the text of the report that follows. They are not summarized here because of the extensive backup material needed for their proper presentation.

The following list gives the page numbers of the more important additional recommendations and comments:

Chapter I

INTRODUCTION

We firmly believe that the public now wants a clean environment. Man's environment has been neglected for many years. For too long we have drawn water from the spigot without concern for how it reaches us. For too long we have poured water down the drain without regard for its ultimate pollution potential. For too long we have seen or heard the trash being collected without concern for the conditions which result from its final disposal. A passive attitude can only lead to critical health problems and to economic stagnation.

In this report we address ourselves mainly to solid waste disposal. Since it is impossible to divorce it from air and water contamination, these areas will be introduced with reference to the major topic. Efforts to improve refuse disposal have lagged behind programs for air pollution and water pollution control. The reason for its position is not surprising; first, the public has not been made to recognize the problem, therefore has not demanded action; then, there have been no dramatic epidemics to emphasize the health problems; and, finally, governmental agencies have not set standards and monitored the operation of refuse disposal sites.

In addition to the public health implications, the economic impact on the taxpayer should be a stimulus to action. McKee[1] presented an analysis of Los Angeles County which would be applicable for any large metropolitan area. His conclusion was that "the solid waste problem is over four times as large as the liquid-waste problem on a dry weight basis, slightly larger in total annual cost, and over three times as large on the basis of annual operating costs." Yet, if one compares total effort concentrated on cost reduction and improved technology in solid waste with the effort for liquid wastes, one finds that the solid waste field has been neglected. We hope this report stimulates interest and action in this most important area.

In this report we consider various aspects of solid waste collection and disposal. Today each community has refuse collected either by public employees, or by private contractors, or by the individual bringing it to a designated location. No matter which method of collection is used, it represents a substantial cost to the taxpayer. This then introduces the first goal of any solid waste management program-improved collection methods. Each community or group of communities should examine carefully its present collection system with regard to incorporation of such things as modern collection vehicles and route selection techniques. Cooperation between communities for their mutual benefit should also be considered. The results of such studies would, in many instances, lead to a reduction of cost and possibly improved service.

The second goal of any solid waste management program is a better disposal method. Today each community has a method of ultimate disposal. Some are satisfactory, while others are public health and safety hazards. A study and evaluation of disposal methods would not normally lead to a cost savings. Just the reverse would be true. After a critical review the taxpayer would be asked to contribute to a clean, healthy and safe environment by raising the standards of the present disposal method. In this endeavor the Commonwealth can contribute to progress through scientific communications activities, as previously noted. The Commonwealth could play an important role in such evaluation studies by setting up guidelines and disseminating the most up-to-date information. It would also be valuable to "translate" some of the highly technical journal information to something understandable and useful for the non-Ph.D. sanitation workers.

A major problem in solid waste management is that, frequently, an optimum solution for a community is found by a joint effort with a neighbor which requires crossing political boundaries. Here the Commonwealth can function to bring together, on a regional basis, the separate political entities for the benefit of all.

To summarize then, this report deals with recommendations which both increase and decrease the cost to the taxpayer, but with the ultimate aim being the efficient control of our environment.

[1]McKee, J. 'Dimensions of the Solid Waste Problem," Proceedings of the National Conference on Solid Waste Research, A. P. W. A., December, 1963.

TABLE 1

Refuse Materials By Kind, Composition, And Sources[1]

	Kind	Composition	Sources
REFUSE	Garbage	Wastes from preparation, cooking, and serving of food; market wastes, wastes from handling, storage, and sale of produce	Households, restaurants, institutions, stores, markets
	Rubbish	Combustible: paper, cartons, boxes, barrels, wood, excelsior, tree branches, yard trimmings, wood furniture, bedding, dunnage	
		Noncombustible: metals, tin cans, metal furniture, dirt, glass, crockery, minerals	
	Ashes	Residue from fires used for cooking and heating and from on-site incineration	
	Street Refuse	Sweepings, dirt, leaves, catch basin dirt, contents of litter receptacles	Streets, sidewalks, alleys, vacant lots
	Dead Animals	Cats, dogs, horses, cows	
	Abandoned Vehicles	Unwanted cars and trucks left on public property	
	Industrial Wastes	Food processing wastes, boiler house cinders, lumber scraps, metal scraps, shavings	Factories, power plants
	Demolition Wastes	Lumber, pipes, brick, masonry, and other construction materials from razed buildings and other structures	Demolition sites to be used for new buildings, renewal projects, expressways
	Special Wastes	Hazardous solids and liquids: explosives, pathological wastes, radioactive materials	Households, hotels, hospitals, institutions, stores, industry
	Sewage Treatment Residue	Solids from coarse screening and from grit chambers; septic tank sludge	Sewage treatment plants; septic tanks

[1] "Municipal Refuse Disposal," A.P.W.A., 1966.

Solid Waste Defined

The term "solid waste" is synonymous with "refuse." It is composed of a wide variety of useless, unused, unwanted or discarded materials from residential, commercial and industrial activity. A standard classification is given in Table 1. Each community, or even each sub-section of a community, has its own typical variation in quantities of each component which taken collectively are considered solid wastes. Factors such as the time of the year, rainfall, and separate or combined collection also all contribute to variations in the chemical analysis of a refuse sample. It, therefore, is misleading to talk about any set analysis or average composition of refuse. Analysis of ordinary refuse would be expected to have the following ranges:

Item	*Percentage by Weight*
Combustible	50-85
Non-combustible	20-40
Water	20-30

The Metropolitan Area Planning Council (MAPC) report[2] for the 83 cities and towns in Boston and vicinity notes that domestic refuse composition in the metropolitan area was found to be 85% combustible and 15% non-combustible.

Two other characteristics of refuse of importance are the weight and the stability. Again it is necessary to refer to ranges because of the extreme variability. Expected ranges of weights are as follows:

Condition	*Weight (pounds per cubic yard)*
Uncompacted (as collected) refuse	200-300
After collected in compaction vehicle	400-500
Well compacted landfill	700-1000

The stability of solid waste is the controlling criterion for determining the nuisance potential generated by storage. The stability is directly proportional to the percent of garbage in the refuse; i. e., the greater the garbage content, the less stable the waste. This is another factor which is unique for each subsection of a community.

Quantity of waste is also quite variable. Social and economic factors have an impact on the quantity of refuse discarded. Table 2 indicates the quantities of refuse generated, averaged over the year, for various cities in the United States.

Considering Table 2 and other data collected, the usual typical values used in terms of pounds per capita per year are 200 for garbage and 1300 for rubbish, a total of 1500. This represents a value of approximately 4.1 pounds per capita per calendar day. Some cities have determined values as low as 2 and as high as 8 pounds per capita per day. Using an average figure, the total solid waste production for Massachusetts per year is 7.7 billion pounds or approximately 30 million cubic yards. These quantities represent a sizeable disposal problem for the Commonwealth. A study[3] of refuse quantities in the Boston area showed an approximate value of 1,062 pounds of rubbish per capita per year. This figure does not include garbage production which would bring it closer to the national average. In the past garbage has been disposed of at piggeries but this practice is declining. It is expected that both the population and per capita production of refuse will increase in the future. A figure of 2% increase per year seems to be a reasonable value for the increase in per capita production.

[2]Metropolitan Area Planning Council Report, "Solid Waste Disposal Program for Metropolitan Boston," Vol. I, Part I.

[3]Karaian, V., unpublished Master's Thesis, Tufts University, Medford, Mass.

TABLE 2

Quantities of Refuse Collected (1957-1958)[1]

City	Pounds per capita per year
St. Petersburg, Florida	1690
Los Angeles, California	1677
Washington, D. C.	1638
Chandler, Arizona	1587
Garden City, New York	1438
Hartford, Connecticut	1430
Seattle, Washington	1370
New York City, New York	1325
Atlanta, Georgia	1252
Cincinnati, Ohio	1103
San Francisco, California	794

[1] Quantities include garbage and rubbish. Data from "Municipal Refuse Disposal," APWA, 1966.

Cost Information

We have discussed quantities of solid waste and in this part we will attach approximate costs to these quantities. The U. S. P. H. S. has estimated the total national cost for solid waste collection and disposal as three billion dollars annually. At this point it is interesting to bring out the research and development aspects of refuse disposal. Industrial practice normally considers an investment of approximately 5% of the gross income to be a reasonable effort on research activities. This rule of thumb applied to solid waste calculates to be a $150,000,000 investment annually. The research budget for the U. S. Solid Waste Program falls far short of this level.

There is no complete cost information available for the Commonwealth as a whole. For estimating purposes we will use a collection estimate of $4 per capita per year and a disposal figure (for less than desirable methods) of $1 per capita per year. An approximate estimate for the annual cost of solid waste collection and disposal in the Commonwealth would be 25 million dollars. It is obvious that we are not devoting enough effort in the form of cost efficiency studies and improving technology that so great an expenditure of money deserves.

These estimates do not take into account the capital investments required for the construction of new disposal facilities such as incinerators. An example of the magnitude of the investment required can be shown by the proposed MAPC[4] plan which will service approximately 2.6 million people; the recommended capital improvement program calls for an expenditure of $84,000,000 over a three year period.

[4]See reference 2.

Land-Air-Water Complex

The total environment must be considered and dealt with as a unit. It is not possible to concentrate on solutions for one problem without having an effect on other areas also. To illustrate this point, solid waste disposal may be considered. Burning of refuse contributes to air pollution and is in turn affected by air pollution control measures and standards. Landfill disposal may constitute land pollution and can have a deliterious effect on ground or surface water in the proximate area. Garbage grinders which provide a partial solution to solid waste problems introduce problems in liquid waste disposal both in treatment plants or the water-course used for final disposal.

The importance of this land-air-water complex has been noted in recent waste management studies including the California Waste Management Study by the Aerojet General Corporation;[5] Waste Management and Control report of the National Academy of Science;[6] and a report of the Environmental Pollution Panel of the President's Science Advisory Committee.

Activities of the Commonwealth should, concerning land, air and water management, carefully consider the interrelated aspects of the total environment. A conscientious effort should be made to have a continuing coordination and communication between all of these State efforts.

[5] "California Waste Management Study," A Report to the State of California, Department of Public Health. Aerojet General Corp., Report No. 3056 (Azusa, Calif., 1965).

[6] "Waste Management and Control," Publication 1400, National Academy of Sciences—National Research Council, Washington, D. C., 1966.

Chapter II

ORGANIZATION FOR SOLID WASTES MANAGEMENT

Introduction

This chapter describes the existing organizations for solid wastes management at the Federal, State, and local levels. Our discussion covers matters concerning organization, personnel, and legal powers for administering programs for solid wastes management.

State Organization for Solid Waste Management

Organization

The present organization of the Division of Sanitary Engineering of the Department of Public Health (DPH) is shown in Figure 1. About 60 professionally trained individuals are employed by the Division in five headquarters sections in Boston and Lawrence and four field offices.

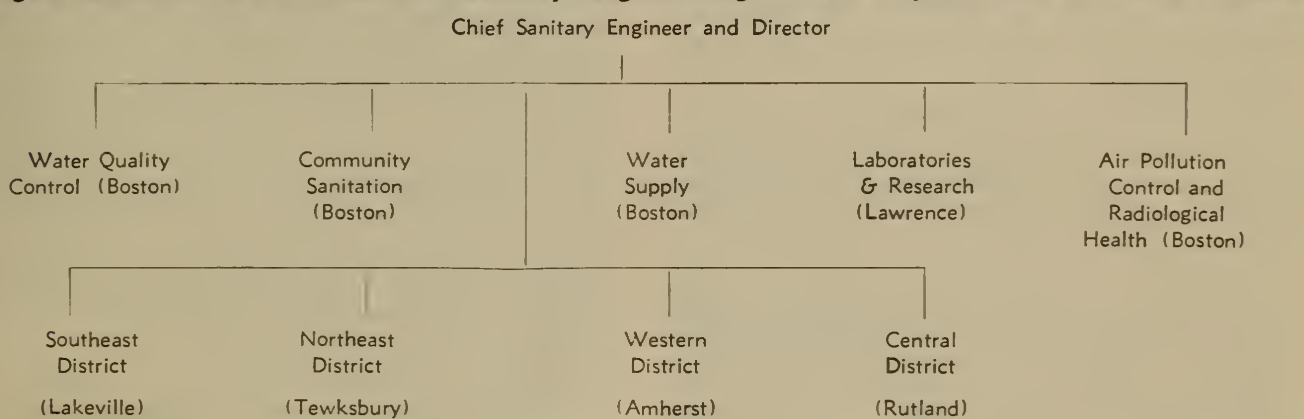
The activities relating to solid wastes are in the section on Community Sanitation, and in the district offices. The solid wastes function is only one of 13 functions assigned to the Community Sanitation section (which also has responsibility for such major efforts as rodent and insect control, housing, recreational sanitation, etc.), and only one of approximately 25 functions assigned to each of the district offices. The Community Sanitation section consists of 3 men, and each of the districts is staffed by 5 or 6 men. The effect of this obvious understaffing is that only about 1.5 men on the average is engaged in solid wastes activities at any time, and only one individual can devote as much as 60% of his overall effort in this field. As a result, the DPH has had to assume a relatively passive role in solid wastes activities to the extent, for example, that it usually acts upon a complaint concerning a local solid wastes problem only after a formal petition has been presented, signed by at least several complainants.

Planning Activities

The problems which can be traced to insufficient personnel should be partly ameliorated when the DPH actively pursues the "solid waste disposal planning project" which has been approved by the U. S. Public Health Service. Under this three year project with a total budget of $180,000 provided by the PHS and the State in equal shares, a survey would be made of present collection and disposal practices for solid wastes, and a general plan would be created for the overall regulation and control of waste disposal practices throughout the Commonwealth. The project would work with other State, local and Federal agencies in establishing this plan. Four sanitary engineers, and a support-

FIGURE 1

Organization of the Division of Sanitary Engineering of the Department of Public Health



ing staff, would be assigned to the project on a full-time basis and consultants would be used after the first year of the program. It will undoubtedly be necessary to continue the project staff beyond the currently authorized Federal funding period.

Unfortunately, the Commonwealth has not yet authorized its share of the project and thus the DPH has been unable to proceed. Irrespective of other solid wastes management programs contemplated by the executive agencies and the legislature, we feel that approval of the necessary funds is a matter of highest priority and should be accomplished at the earliest possible moment. Because of the delay, it is already going to be very difficult to recruit June 1967 college graduates who would comprise the bulk of the technical staff.

The new staff for the project plus the one or two men equivalent now engaged in solid wastes activities would probably be adequate for currently planned DPH programs. This staff will not be enough, however, considering the additional regulation activities the agency should have, as discussed below.

The salaries and civil service requirements in Massachusetts State and municipal government, pertaining to solid wastes specialists, such as sanitary engineers, are so inequitable when compared to the salaries and other aspects of Federal and private employment, that we are not optimistic that the needs for personnel of the State, regional, and local governments will be properly met. While most major planning and design of disposal installations can be made by Consulting Engineers, there remain approval and monitoring functions and operations management that must be provided by government. We wish, accordingly, to add our voices to those who are actively seeking to improve conditions for engineers and other technical professionals in Massachusetts government.

Legal Authority

There are ten existing legislative acts which affect the management of solid wastes. These are outlined as follows:

(1) Chapter 129—Section 14A and 14B of General Laws (Ch. 655—Acts of 1953). Cooking of garbage to be fed to swine for at least 212°F for at least 30 minutes or treated in some other approved method.

(2) Chapter 111—Section 150A (Ch. 310—Acts of 1955). Assignment of place for dumping ground or site for incinerator by local Board of Health.

(3) Chapter 111—Section 142B (Ch. 676—Acts of 1960). Formation of the Metropolitan Air Pollution Control District and control of pollution of the atmosphere within the district.

(4) Chapter 40—Sections 44A—44K (Ch. 748—Acts of 1965). Formation of regional refuse disposal districts for the construction, maintenance and operation of refuse disposal facilities to serve the needs of the district.

(5) Chapter 131—Section 177C (Ch. 220—Acts of 1965). Provides for the protection of flood plains by forbidding persons to remove, fill or dredge any bank, flat, marsh, meadow or swamp bordering on any inland waters without prior permission from the Mass. Dept. of Natural Resources.

(6) Chapter 130—Section 27A (Ch. 426—Acts of 1963). Regulates removal, filling and dredging of areas bordering on coastal waters without prior approval of Mass. Dept. of Public Works and Mass. Dept. of Natural Resources.

(7) Chapter 40—Section 8C (Ch. 258—Acts of 1961). Provides for establishment of conservation commissions in municipalities for promotion and development of watershed resources of city and town.

(8) Chapter 111—Section 142A (Ch. 422—Acts of 1959). Enabling legislation for state-wide control of air pollution by DPH.

(9) Chapter 111—Section 142C (Ch. 660—Acts of 1966). Formation of the lower Pioneer Valley air pollution control district and other future pollution control districts.

(10) Chapter 111—Section 31C (Ch. 672—Acts of 1954). Enabling legislation allowing local boards of health to adopt rules and regulations for control of air pollution.

Of the above, the second relating to the assignment of disposal locations and the fourth relating to the formation of regional disposal districts are discussed below in some detail.

Under the law concerning assignments, each local community Board of Health has the authority to assign a site for a dumping ground or for a refuse disposal incinerator. Although the Department of Public Health may be consulted before the assignment, this is not required by the law. Once the assignment has been made, the Department upon petition or upon its own initiative has the power, after due notice and public hearing, to rescind or suspend such assignment, or to modify the same by the imposition or amendment of conditions, if the operation is judged to be a nuisance and danger to public health.

In addition to the obvious difficulties of correcting a local problem by State action, due to the

lack of adequate manpower and the necessity for protracted formal proceedings, other aspects of the law are deficient. The law covers only dumping or incineration as possible disposal alternatives and does not specify what is meant by a sanitary landfill, which is the only dumping procedure meeting acceptable environmental conditions. It is also believed unlikely that a local Board of Health can be sufficiently knowledgable concerning what is essentially engineering practice, in addition to its medical functions.

Changes to the above law were proposed in the current legislative session, under H-2073 and H-2074, but were not passed. Under H-2073, (1) the assignment function of the local Board of Health would include not only dumping grounds and refuse disposal incinerators but also transfer stations and refuse composting plants; (2) all existing and future dumps would have to be operated as sanitary landfills, in accordance with rules and regulations of the Massachusetts Department of Public Health. Under H-2074, designs for transfer stations, incinerators, and composting plants would have to be approved by DPH.

We regret that the proposed changes were not favorably acted upon, and we recommend resubmittal to the legislature at the earliest possible date. We recommend that the bills be amended to require that all refuse disposal sites including landfills, all refuse disposal works, and all transfer stations and long-haul transportation schemes for solid wastes be approved by the DPH before development. We recommend further that the DPH be empowered to establish regular inspection of such facilities to ensure proper functioning. In our opinion, these measures are necessary for proper management of refuse disposal operations throughout the state, equitable treatment from aesthetic and public health standpoints of all citizens in the control of the aspects of their environment affected by solid wastes operations, proper coordination with Federal and State planning and construction programs, and appropriate incorporation of the latest technical improvements and innovations indicated by on-going research.

The following discussion concerns other laws and financial incentives for regional districts, the Department of Public Works (DPW), and the Metropolitan District Commission (MDC) to construct and operate disposal works. Essentially the same regulatory controls administered by the DPH should apply to all solid wastes activities, including those of individual municipalities, regional districts, the DPW, and the MDC. This is not to suggest that an equal amount of effort per person served would be necessary on the part of the DPH to ensure that the solid wastes management techniques employed are suitable, since the construction and operating agencies should have their own qualified staffs.

There were four bills concerning solid wastes management in 1967: H-4540, H-4541, H-4559, and H-4907. The first two of these bills were intended to facilitate the formation of regional solid wastes disposal districts by both contiguous and non-contiguous cities and towns, and the whole or portions of the City of Boston. Under the authority of Chapter 748 of the Acts of 1965, regional refuse planning committees and boards have been formed to consider the possibilities for joint management, but no districts have actually been formed. The main feature of the bills were a requirement for approval by the DPH of the design of disposal facilities, and a provision for grants of up to 30% of the cost of establishing an incinerator, sanitary landfill, transfer station, composting plant, or other sanitary means of solid waste disposal.

A later section of this chapter discusses Federal programs that are available for subsidizing the planning of public works. These programs have not been fully effective, and we have the impression that a need exists for additional State assistance for both preliminary and definitive planning of projects. We believe that State funds should have higher priority, at the present time, for planning rather than for construction. Any construction funds authorized by the Legislature would probably be limited. A good foundation does not exist, in local, regional and State-wide plans, as a basis for a proper review of applications for construction funds. As a result, the allocations of limited construction funds may be inequitable, and communities could delay the initiation of waste management measures while awaiting such funds. If it is desired to provide State subsidies for more than planning, support may be considered for operation and maintenance after communities have shown good faith by investing in appropriate waste management construction.

The approval for construction and operation by an individual community, by a district, or by the DPW or MDC, should be given only after careful consideration of technical, economic, and administrative details. We can set up at least one situation in which a community, poor in land for disposal sites or poor in terms of central location for transportation, would have difficulty convincing adjacent communities to join with it in a regional plan. There should be some means, regulatory or finan-

cial, for the DPH to ensure reasonably appropriate groupings of communities for waste management.

House bills 4559 and 4907 would, respectively, authorize the Department of Public Works and a Metropolitan Solid Wastes Disposal District to establish, maintain and operate solid waste disposal facilities. The latter district would essentially be the region of Metropolitan District Commission, and hearings have established that the operating authority would be the MDC. The DPW bill would set an initial charge not to exceed $3.00 per ton for municipalities while the MDC would set charges to recover costs. There would be an advisory board for the MDC plan comprised of at least one member from each municipality in the District. The DPW bill requires approvals of facilities from the DPH and DNR, while the MDC bill requires approvals of facilities by the advisory board, the Metropolitan Area Planning Council, and the Department of Public Health, and a review by the Department of Natural Resources.

It has not been possible within the scope of this report to analyze the exact wording of the regional district bills, the DPW bill, and the MDC bill, or to investigate and evaluate all of the political, administrative, and economic implications of the bills. We can, however, summarize our general attitudes toward the bills as follows: (1) we agree with the general purposes of the bills in encouraging the construction of disposal facilities through regional action (however, as discussed elsewhere, we do not believe that all of the best solutions are regional solutions); (2) we feel the DPH should review and approve all plans before construction; (3) we feel the DPH should periodically review operation of facilities; (4) we believe the DNR, and other government agencies when appropriate, should make reviews of projects at inception and during construction and operation, and should transmit findings to the DPH who should negotiate with the regional construction and operation agency in effecting changes which it deems necessary, and (5) a suitable review procedure should be available for problems which cannot be resolved at lower levels.

Regional and Local Organization

In the discussion presented above for State organization, we have included a number of comments concerning desirable regulation by State-level executive agencies of the construction and operation activities of regional and local organizations. The following section deals primarily with the planning activities of regional and local organizations which do not have capability or legal authority to construct and operate installations.

Metropolitan Area Planning Council

The MAPC is an official agency of the Commonwealth of Massachusetts. It was established by Chapter 668 of the Acts of 1963 to provide for metropolitan planning in the Boston Area. The Metropolitan Area Planning District, which is served by the Planning Council, currently consists of 83 cities and towns, including Boston, with a total population of 2.6 million persons. The Council is financed by per capita assessments (amounting to about 3.5 cents per capita annually at the present time) and by Federal grants.

Under a Federal planning grant made in 1965, three comprehensive studies are now underway: (1) open space and recreation planning; (2) solid waste disposal plan; and (3) work program development. Previously completed by the MAPC were a preliminary open space and planning study (December 1965, with Dept. of Commerce and Development and Dept. of Public Works); a Southwest Corridor Study (July 1965 with Dept. of Public Works, BRA, MBTA, and Boston DPW); and an economic base and pouplation study (January 1966 with Dept. of Commerce and Development and Dept. of Public Works).

About five men have been involved in a 2 year study of the solid wastes problem for the Boston area. Outside assistance was sought from consultants and from a Technical Advisory Committee appointed by the Council.

An initial report on solid wastes was recently prepared by the MAPC[1] and made available to us for use in our study.

The MAPC report, together with companion volumes II and III to be released later, "is intended to cover the following subject matters:

1. A recommended program of action, the program based on:
2. An inventory and evaluation of the types of amounts of solid wastes to be disposed in the next 25 years in the Metropolitan Area.
3. An analysis of the technical means for disposal of solid wastes, present and potential.
4. An analysis of the administrative and financial means—both available and required."

A system of nine regional incinerators and eight sanitary landfill operations is recommended for construction through 1990. It is stated that five of

[1] "Solid Waste Disposal Program for Metropolitan Boston" —Volume I, Part I and Part II, a review draft with no date.

these incinerators are needed now and should be given highest priority. A total capital improvements cost for new facilities of $84,000,000 is estimated. The MAPC recommends that the Metropolitan District Commission be designated as the agency to carry out the planned solid waste disposal program. The proposed enabling act is discussed elsewhere in this chapter.

In general, costs are to be shared by member communities proportionately, on the basis of actual tonnage delivered to a regional facility. Commercial and industrial firms are to be charged on a per ton basis, using an established fee schedule. Participation in the plan is voluntary on the part of municipalities but all members of the District would share overhead and planning expenses.

Collection and delivery to regional facilities is to be the responsibility of each community. The MDC would operate the regional facilities. Landfills would be located outside Route 128, where land is available, and each would handle around 220 tons per day by 1975 and 375 tons by 1990. Incinerators would be located on or near major expressways and in the center of high refuse production zones, would range in capacity from 800 tons to 1800 tons per day, and would be constructed in stages. The MAPC anticipates that all of the existing community incinerators and individual community landfills will be phased out during the planning period; the system of facilities would be designed and from time to time redesigned to serve only those communities that wish to use the regional system. A schedule is given in the review draft of Volume I for accommodating each of the cities and towns.

Volume II of the report will be a discussion of site selections and Volume III will cover the economic backup data for the cost estimates of Volume I.

We have reviewed the material of Volume I, in the light also of information received from the staff of MAPC.[2]

Our general impressions of the report are as follows:

1. A rational approach was taken in studying the problems of the Boston area. Systems analyses were, in general, made in the traditional sense. Mathematical systems analyses and computers were not relied upon for substantial support.

2. Plans and cost estimates for facilities were based upon existing practice. Brief summary descriptions are given of advanced technologies and imaginative innovations under investigation and development by others, but none of these is encouraged by the planners as being suitable for adoption at an early date.

3. Perhaps because of the large number of governmental interests affected and the delicate nature of the involvement of the planners, an in-depth study was not made of the desirable degree of participation of individual communities. It is thus difficult to judge the optimality of the specific locations and sizes of facilities and time tables for development.

4. Participation by communities would be optional. However, estimates have not been made of the effects on specific costs if a number of communities did not choose to join regional plans.

We believe the report has made a good case for regional development. We have not been able to form a judgment as to whether the MDC or another single agency should construct and operate all of the regional facilities, or whether there should be several district agencies; it is not entirely reasonable to draw a parallel with the MDC operations in water supply and sewage disposal which have been very effective for regional management. If it is considered highly likely that, because of political considerations, communities could not form a number of districts, this would be an excellent reason to favor a single entity for planning and operation.

Succeeding parts of our report will discuss technological aspects of solid waste disposal. We believe that a thorough study should be made of each facility before construction, with a full analyses of the regional operation as compared with individual community operation, and with adequate comparison with alternate means of disposal. The facility design should be made by expert firms of consulting engineers who should be encouraged to incorporate the latest proven technological improvements. Because of the strength in a large total capacity, a regional agency should be willing to innovate and experiment with portions of that capacity in hopes of a good pay-off.

It is, perhaps, somewhat inconsistent to have a recommendation in the MAPC report for optional community participation along with a plan of incinerators and landfills that can handle the entire area. Adequate response of communities is needed in order to gain the economies of large installations.

[2]Information given in discussions with W. Melia, director of the solid wastes study for MAPC, on February 17, and May 16, 1967.

Lower Pioneer Valley Regional Planning District

This planning district comprises an urban, suburban, and rural area, including 23 municipalities, of which the principal ones in terms of population are Springfield, Chicopee, and Holyoke. The population of the district is 0.5 million persons. In March 1964, the District Commission started on the first stage of a federally assisted (U. S. Housing and Home Finance Agency, now under HUD) long-range planning program which includes studies on the economic and physical structure of the region, and regional and subregional services and resources. A domestic refuse and industrial waste collection and disposal study was prepared by The Planning Services Group of Cambridge and published in November 1964.

Among the recommendations of the report were that refuse collection should remain the responsibility of individual municipalities, open dumps should be converted to sanitary landfill operations, additional sanitary landfill developments were necessary, excess capacity of Holyoke's incinerator may be made available to other communities, and additional disposal facilities were necessary and appeared appropriate for subregional cooperative use. The recommendations concerning type of final disposal facilities were indefinite due to the preliminary nature of the report in this regard.

Central Massachusetts Regional Planning District

The only other regional planning study of refuse collection and disposal known to the authors is centered in the Worcester area. This study is just getting under way, under a plan whereby 2/3 of the cost is from the Department of Housing and Urban Development, and 1/3 is from the 24 member communities of the planning district. The population of the planning district is about 0.4 million persons.

Comments Concerning Regional and Local Planning

It is logical to us that solid wastes management planning should be done on a regional basis. As outlined above, the studies for the metropolitan areas of Boston, Springfield, and Worcester cover a combined population of 3.5 million persons out of the 5.3 million total 1965 population of Massachusetts. Areas within the Commonwealth that have not been studied and are obvious candidates for regional studies are the Pittsfield region, the Fall River - Taunton - Brockton area, and the Greater Lawrence area.

In general, we prefer to see the collection function remain with the individual municipality. Where close contact is necessary with the person or business served, there are advantages in retaining the administration at this level, because of the opportunity for easy confrontation of responsible parties in the case of complaint, and because of political considerations. There ought to be the possibility of intervention by higher levels of government, however, for compelling reasons associated with unsatisfactory public health practices. As we become more sophisticated in our views of environmental conditions of the air-water-land complex, it is likely that our interpretation of unsatisfactory public health practices will broaden. Also, we indicate elsewhere in this report that collection operations could probably be improved and state agencies ought to have the capability and the working arrangements to assist local governments with appropriate studies.

We are not convinced, as engineers involved with both general planning and detailed design, that the best solutions for solid waste management are always regional solutions. Where existing individual communities now have satisfactory means of disposal, it is probably not to their immediate advantage to join regional operation plans unless excellent economic incentives were available. In the case of only small apparent economic gains, the municipality may prefer to have its own facilities rather than face the other uncertainties of a regional plan. In the long-run, however, the community may stand to gain considerably from regional operation, in being able to trade off current excess capacity against the future benefits of using facilities owned by other communities or the regional authority.

Similar logic would apply to the individual community considering the installation of a new or improved means of disposal. Here, however, the community may have fewer doubts about joining a regional plan, because a local solution may have insufficient support from its citizens and inadequate financial backing.

It is obvious that if regional plans are to be successful it is necessary to show that the regional operation is feasible from an engineering standpoint, and economically workable. It is more difficult to show by engineering and economic analyses that the regional plan is attractive in terms of the interests of each of the municipalities. Political and grass-roots support will not follow unless all of these tests of viability can be satisfied. If regional participation is to be voluntary on the part of the municipalities, as appears to be the sentiment as expressed in the MAPC report and in various pieces of existing and proposed legislation,

better presentations are needed of the engineering and economic advantages of regional cooperation than we have been able to examine so far.

Such presentations should include a complete organization and operation chart, and detailed estimates of costs including haul costs from individual municipalities. Costs of regional operations should be compared with those for individual municipalities. Costs ought to be developed to indicate various levels of operation to accommodate different degrees of participation of municipalities, and for various stages of growth of the regional plan.

Federal Organization

Solid Waste Disposal Act of 1965

This act (Title II of P. L. 89-272, 89th Cong. S. 306 October 20, 1965) authorizes a research and development program with respect to solid-waste disposal. The aspects of disposal resulting from generation of solid wastes in municipalities is administered by the Department of Health, Education and Welfare. The agency within HEW which administers this program is the Public Health Service, National Center for Urban and Industrial Health, Solid Wastes Program (formerly Office of Solid Wastes). The purposes of the act are:

"(1) to initiate and accelerate a national research and development program for new and improved methods of proper and economic solid-waste disposal, including studies directed toward the conservation of natural resources by reducing the amount of waste and unsalvageable materials and by recovery and utilization of potential resources in solid wastes; and

(2) to provide technical and financial assistance to state and local governments and interstate agencies in the planning, development, and conduct of solid-waste disposal programs."

It is under the second purpose of the Act that the Office of Solid Wastes approved the grant for planning by the Massachusetts Department of Public Health. This grant has been discussed above.

The act authorizes the expenditure of $60 million by HEW over a four year period (Fiscal years 1966-1969 inclusive). The rate of appropriation has been considerably less than the authorized amounts. Between the enactment of the act in October, 1965 and about May, 1966 some 32 projects in all parts of the United States are being developed to demonstrate new and improved methods of collecting, processing, and disposing of solid wastes. These projects are receiving grant support from the PHS in the amount of nearly $3.9 million. Twenty-five states have begun comprehensive surveys of their solid waste problems, combined with the development of plans for solving these problems, assisted by Federal grants totaling $9.0 million. Research projects are receiving nearly $2.0 million in grant support.

Research and demonstration projects are summarized elsewhere in this report. They are designed to develop an understanding of the extent of the solid wastes problem and to develop new approaches toward collection and disposal techniques, possibilities for productive salvage and reuse of waste materials, and regional solid wastes management.

It is interesting to note that the Solid Waste Disposal Act was Title II of an act in which Title I consisted of amendments to the Clean Air Act. The implications of this pairing are significant.

Proposals to Amend the Solid Waste Disposal Act

Under Senator Edmund S. Muskie's leadership, a bill to amend the Solid Waste Disposal Act has been introduced (S. 1646 and a companion bill H. R. 9477). Under this bill, the authorized amounts for fiscal years 1968-1972 would be increased to $810.8 million. The intent of the bill is to advance the Federal program from the research-development-pilot stage into a vast national construction effect which would also materially reduce air pollution.

The following are the principal provisions of the proposed bill:

Planning Grants. State, interstate, municipal, and intermunicipal agencies would receive grants of up to 66 2/3% for single municipalities and 75% for more than one municipality. Such grants would have to include plans for reuse of solid waste disposal areas and studies of effects of such areas upon adjacent sites.

Construction Grants. Appropriation authorizations for HEW would be increased from present $19.2 million in fiscal 1968 to $46 million; from $20 million in 1969 to $83 million; and extended beyond present 1969 limit to $152 million in 1970; $216 million in 1971; and $236 million in 1972. Authorizations to the Dept. of Interior for mineral and extractive industries would also be increased. Funds appropriated would remain available until expended, a provision not appearing in existing law.

An important feature of the bill is that it would be possible to receive construction support without the necessity of showing that the project is a demonstration grant. Construction grants would be up to 66 2/3% Federal aid for a single municipality and 75% for an intermunicipality project.

Senator Muskie has been the prime mover of legislation in the field of air and water pollution and solid wastes. The role of the Federal government in water pollution control in the last few years has changed from the relatively passive activities of the Public Health Service in research and advisory services offered to counterpart State health agencies, to an active intervention in all aspects of the problem and at all levels of government. If it is permissible to draw a parallel between the water pollution control effort of the Federal government and its activity in air pollution control and solid wastes disposal, it may be expected: first, that Senator Muskie's bill to increase Federal support will probably be passed, in the near future if not at this session of Congress, and second, that construction aid by the Federal support will be coupled with fairly extensive policing of the program. Even if the bill is passed, however, it may be a number of years before authorized funds would develop into appropriated funds.

Housing and Urban Development Grants

The planning studies for the metropolitan Boston, Springfield, and Worcester areas were financially assisted by Federal grants provided under Section 701 of the Housing Act of 1954, as amended.

The Department of Housing and Urban Development has four programs of interest to public bodies which plan and construct solid waste facilities. They are as follows:[3]

1. Urban Planning Assistance Program. For preparation of comprehensive development plans, including the provision of public facilities. Provides grants up to two-thirds of the cost of the work (in some cases, as much as three-quarters).

2. Grants for Advance Acquisition of Land. Provides grants covering the interest charges for 5 years on a loan incurred to finance the acquisition of land.

3. Open Space Land and Urban Beautification Grants. Provides grants of up to 50% of the cost of acquiring, preserving and developing urban lands having value for park, recreation, scenic or historical purposes.

4. Advances for Public Works Planning. Provides interest-free advances, repayable upon start of construction, to assist planning for individual local public works and for area-wide and long-range projects which will help communities deal with their total needs.

Training in Solid Wastes

The Massachusetts Department of Public Health has no active programs for the training of specialists in the solid wastes field. There are programs available for the training of engineers and first-level administrators by the Federal government and by universities. However, the DPH should develop training programs for training technicians and second-level administrators.

The U. S. Public Health Service has supported some nationwide seminars and has also made some grants to universities for training in solid wastes. The PHS also runs a number of one-week training courses at its training center in Cincinnati and elsewhere. For fiscal year 1968, there are seven courses entitled: environmental solid waste orientation; elements of solid waste management; solid waste handling—health and safety; solid waste handling — field evaluation; sanitary landfill — principles of design and operation; incineration—principles of design and operation; and composting methods.

There has been relatively little activity in solid wastes training by universities in Massachusetts. However, there are some encouraging signs. A seminar last year on solid wastes at Northeastern University was very well attended. Also, some students in the Master's program in Sanitary Engineering chose to write Master's reports or term reports on subjects related to solid wastes. Northeastern has just received two five-year training grants from the U. S. Public Health Service which provide assistance to students and to curriculum development in environmental health engineering and science. We expect that specialists will be graduated each year from Northeastern (and from other Massachusetts universities), qualified in solid wastes technology and related work such as air pollution, who could assume key positions in the administration of the programs of the Commonwealth, provided that salaries and working conditions were competitive with other offers.

[3] "Programs of the Department of Housing and Urban Development," Washington, D. C., November, 1965.

Chapter III
SOLID WASTE COLLECTION AND TRANSPORTATION

Introduction

At the outset of this chapter, we offer the following quotations from the publication, "Refuse Collection Practice," of the American Public Works Association:[1]

"The activities of the municipal refuse collection departments are more continuously in the public eye and relate more closely to the daily lives of citizens than those of any government service. There is no better opportunity to promote good relations between the public and the municipal administration than by providing courteous, sanitary, efficient removal service."

"The collection and removal of municipal refuse—one of the major problems of American cities—has been given less attention than this essential public function deserves. Only within relatively recent years have most municipal officials been willing to admit that refuse disposal is a technical management problem worthy of their attention and study. Much progress has been made, but still only a minority of communities are using the administrative techniques which generally have proven most satisfactory. Not that methods, equipment, and practices should be uniform over the country. Conditions vary, and it is vital that procedures vary to meet them. However, the problem should be approached the same way in all communities, should be analyzed in terms of sound administrative management, and should receive the same consideration usually given other public health aspects of government."

The above comments are a concise statement of the status of collection practices in the Commonwealth. Overall, we have the impression that few communities have done scientific planning on a regular basis to operate a collection service at minimum cost, consistent with requirements for health and safety and meeting satisfactory convenience and aesthetic standards.

[1] "Refuse Collection Practice," APWA, Public Administration Service, 3rd Edition, 1966.

Collection Practices in Massachusetts

As indicated in Chapter II, surveys are available of the collection and disposal practices of seventy-nine communities in the Boston metropolitan area[2] and of the practices of twenty-three communities in the Springfield metropolitan area.[3] The populations of these areas are approximately 2.6 million and 0.5 million, respectively, constituting about sixty percent of the total population of the Commonwealth of Massachusetts of 5.3 million as of 1965.

With the typical method of collection, garbage and rubbish are separated since the disposal methods are different. Garbage is usually used for hog feeding, while rubbish is delivered to incinerators, sanitary landfills, or open dumps. Most communities have household garbage collected by public or public contract arrangements. In about one-third of the communities, the home owner or business must make his own arrangements for rubbish collection. In the other communities, rubbish is collected by municipal forces or by public contract in about equal proportions.

The average cost of collection, where both garbage and rubbish are collected, is about $4 per capita per year and, depending upon the extent of service and other factors, the range is approximately $0.50 to $9.00 per capita per year. Since the average person in the Boston area generates about half a ton of refuse per year, an average cost of about $8 per ton and a range of $1.00 to $18.00 per ton may be compared with a range for selected large Northern cities outside of Massachusetts of $7.50 to $25.00 per ton.[4]

In the typical operation for rubbish collection for households, 30-gallon metal and plastic containers are placed at curbside for pickup once a week. Packer trucks are used having a capacity of 20 cubic yards which compact the rubbish from a density of about 250 pounds per cubic yard to

[2] "Solid Waste Collection Disposal Program for Metropolitan Boston," Metropolitan Area Planning Council, Boston, publication pending and Master's Thesis, V. K. Karaian, Dept. of Civil Engineering, Tufts University, 1966.

[3] "Refuse Study, Lower Pioneer Valley Regional Planning District," The Planning Services Group, Cambridge, November 1964.

[4] See Reference 1.

about 500 pounds per cubic yard. Garbage is picked up once or twice a week from underground receptacles in back yards, and removed to special 12 cubic yard packer trucks.

The commercial or industrial enterprise usually has its waste materials collected by private contractors, often using large special containers for storage and special trucks to handle them.

Many apartment houses reduce the amount of rubbish to be collected, by employing incinerators. Individual households rarely employ home-incinerators, but garbage grinders are widely used.

By-and-large, innovations as regards refuse and garbage containers and truck equipment have not been considered in Massachusetts.

In general, we have the impression that the collection services in Massachusetts are no more or less efficient than the average collection services elsewhere in the country. The average cost of household collection of $8 per ton for Massachusetts (about $12 per ton for the City of Boston) is somewhat less than recent estimates for Los Angeles ($12.74), Washington ($14.11), Newark ($9.15), Cincinnati ($11.50), Philadelphia ($10.83), and New York City ($24.96). The average rate of pay for collection employees in Massachusetts is generally lower than those in the other cities shown. The large unit cost for New York City is partially because of the congested conditions under which refuse must be collected and transported, but more importantly because of the high labor costs of the strongly organized and politically powerful labor force.

Discussions with researchers who have been interested in investigating collection practices indicate that it is difficult to obtain good cost data in Massachusetts because of the different accounting practices of the cities and towns in the Commonwealth.

Our study has not concentrated on the problems of collection. In a particular location, the collection service may not be entirely satisfactory and may be costing more than necessary. Also, problems exist, particularly in slum areas, with public health or aesthetic significance.

Elements of Solid Wastes Collection

If we can answer the following questions for a community concerning collection practices, we can make a start on an evaluation of current techniques and the prospects for improvement:

1. Where are the following located with respect to service areas: (1) garage; (b) transfer station, if any; (3) disposal area?

2. Is refuse separated into garbage and other solid wastes? Are garbage grinders permitted, or required? Where are the solid wastes placed relative to building on the collection days? What containers are used?

3. How often is each of the solid wastes components collected? Is the collection made during normal working hours or at other periods of the day? How is the assignment, or area to be serviced each day, established for each vehicle and crew?

4. What sizes and types of vehicles are used for collection? What size crew is used for each of these vehicles? Does the driver assist in loading?

5. What routing is used on streets and highways to and from garage, transfer station, collection units, and disposal area? What types of unloading facilities are there at transfer station and disposal area?

6. What provisions are made for collection and disposal of special refuse collection items such as ashes, market refuse, condemned food, dead animals, street cleaning refuse, trees and grass cuttings, hazardous materials, building demolition materials, large furniture and appliances, oil containers, products of spring cleaning and other clean-up drives, and abandoned automobiles?

Status of Solid Waste Collection Planning

A comprehensive discussion of the problems concerned with the last of the above classifications, i. e., special refuse collection items, is beyond the scope of this report. We do not wish to minimize the importance of such problems, but we are compelled by time limitations for this report to focus on the ordinary domestic and industrial refuse which are produced in more or less uniform quantities.

If we concentrate on the first five classifications, and further realize that within each question there may be scores of alternative practices, it is obvious that there are many thousands of possible combinations.

If we consider the following as affecting the system of collection:

1. Hours and days of work for employees, and their morale and efficiency;
2. Equipment maintenance and schedule for replacement;
3. Public and private collection aspects; and
4. Overall considerations of service in terms of the municipal administration and the persons and businesses of collection units;

it is apparent that the establishment of a collection system, or the modification thereof, is a very complex undertaking if done properly. Unfortunately, the system in the average municipality has developed by trial and error, and often changes are made only in reaction to complaints, active salesmanship on the part of manufacturers of equipment, or judgment without field or office analyses.

We do not wish to demean the honest effort of most of our public servants who are involved with collection. However, in relation to the more critical problems of solid waste disposal in many communities, collection is accepted as a routine matter by most individuals. Also, collection can be accomplished without major problems of public health, education and safety, which are the usual subjects for active citizen pressure groups. The result is that collection can be continued using inefficient procedures, without creating public reaction.

As outlined above, planning reports that have been made of the metropolitan Boston area and the Springfield area have indicated collection systems that ranged from municipal-sponsored collection and disposal of all solid waste materials to no municipal arrangements for service. Per capita expenditures for collection thus range to over $10 per year. This is not to suggest that collection service is free when there is no municipally sponsored activity; in these circumstances, the individual must arrange for collection by a contractor or visit the disposal point once or twice a week with the associated vehicle cost and the value of his time.

We know of only a few cases in Massachusetts, where qualified outside consultants have been asked to make comprehensive analyses of a collection system and to provide an adequate review and recommendations concerning methods of improvement. When we consider that in the usual case, the cost of the collection portion is on the order of 75 percent of the total cost of collection and disposal, it is clear that an important deficiency in planning exists.

Accordingly, we recommend that a capability be instituted for planning and improving collection systems and procedures in the Commonwealth. This could be administered by the Department of Public Health and should consist of inhouse activities, such as the preparation of manuals and the availability for advisory services, and the coordination of grants for planning which could be made to individual municipalities or regional organizations. Consulting engineers could be employed to assist and augment State and local personnel. Federal grants may be available for such purposes through the Department of Health, Education and Welfare and the Department of Housing and Urban Development.

We have studied the organization of services of New York State, including the Office for Local Government and the Department of Health, and suggest that these be further studied as a possible model for similar services in Massachusetts.

For reasons of administration discussed in Chapter II, we recommend that in the usual case the collection activity remain a local function administered by the individual town or city. From the cost standpoint, the collection crews are often employed at snow removal and street maintenance which would probably not be possible with a regional operation. Also, it is often found that unit labor costs are higher for the very large organizations because of higher overhead and more forceful labor demands.

When long hauls are involved in order to deliver solid wastes to disposal sites, a regional activity may often be appropriate since the transportation schemes in these cases may be economic only with a regional operation. Suitability of regional or local operation of transportation facilities for the long haul needs to be determined for each case; it is not possible to generalize although it may be stated that the regional operation would most often be the economic solution.

Long-Haul and Special Transportation Facilities

The remainder of this chapter is devoted to a discussion of several methods which are not used extensively in Massachusetts but are of particular interest to those who are currently looking for ways to reduce costs and improve administration of solid waste transportation. These methods include long-haul trucks, railroad cars, and ships.

Transfer Stations and Transportation by Long-Haul Trucks

The manual on refuse collection practice of the American Public Works Association indicates that at least 50 cities in the United States employ transfer stations. In Massachusetts, these include Boston, Needham, Quincy, and Worcester. From a historical standpoint, the use of such stations has changed from fairly regular employment to relatively declining use, to the present time when many cities and regions are again finding them economic.

As noted by the aforementioned reference, when collection vehicles were drawn by horses, it was

common to use transfer stations and supplemental transportation whenever hauls from the collection routes to the disposal points were more than three or four miles long. Sometimes supplemental transportation was employed for even shorter distances when it was obvious that hauling by wagons was more expensive than by railroad, barges or trucks. With the introduction of the faster motor trucks into the refuse collection services, the situation changed radically and many transfer operations were abandoned in favor of direct hauls to the disposal sites.

Where the disposal method is a sanitary landfill or incinerator located relatively near to the service area, the collection vehicle travels directly to the point of disposal, discharges its contents, and returns to the collection route or garage. Where short hauls are not feasible, an economic study may indicate that a transfer station can assist in minimizing total costs, by enabling the transfer of refuse from a vehicle such as a packer truck designed essentially for collection services to a vehicle such as a trailer truck designed essentially for rapid transportation of large loads. There are other circumstances which indicate the desirability of transfer from road vehicle to rail-car or from road vehicle to barge or ship. For example, in Washington, D. C., refuse is transferred to railroad cars for movement to a disposal site close to railroad rights-of-way and in New York City refuse is transferred to barge for movement to landfill in Staten Island.

In Los Angeles, it is reported[5] that the operation and maintenance and amortization costs for a 120 ton per day transfer station and trailer facilities are $2.68 per ton, including a 45 mile round trip haul to landfill sites.

In Orange County, California, the cost with four transfer stations each handling 910 tons per day is reported[6] at $2.33 per ton, including $0.69 per ton for a 6 mile round trip with collection vehicles to transfer station, $0.72 per ton cost of station operation, and $0.92 per ton for about 26 miles haul to landfill sites. The cost of $2.33 per ton is said to compare with $3.65 for a 32 mile round trip for direct haul by collection vehicles. It is seen that essentially we are comparing a cost of 3.5 cents per ton-mile for a trailer, in addition to transfer costs, with a cost of 11.4 cents per ton-mile for a collection vehicle.

There are two general types of transfer. A long ramp or a hydraulic lift system may be used to raise the collection vehicle to a higher elevation for direct dumping to trailers. The second type utilizes storage facilities and rehandling by cranes or wheeled loading machines.

The MAPC report on the Boston metropolitan area[7] states that "the point at which a community decides to replace direct hauling with transfer equipment is often disputed, but serious consideration should be given when haul time exceeds 45 minutes per round trip." The New York State publication[8] suggests that a transfer station is especially suitable for a group of suburban municipalities, with the transfer and disposal accomplished as a joint operation.

We have not been able to define the specific circumstances under which the use of a transfer station would be indicated in Massachusetts. In our view, each case should be decided on the basis of engineering, administrative, and cost comparisons of alternatives. The haul vehicle can be made as large as desired up to the limit indicated by the road system. Much will depend upon the development of collection vehicles. The cities of Chicago[9] and New York[10] have found only limited development of changes and advancements in refuse trucks in recent years. The Chicago experience has been that a 10 or 12 cubic yard body will hold far more refuse by weight, per cubic yard, than proportionately can be put into a 20 or 25 yard unit. And yet it is in the direction of the larger sizes that progress should proceed if the collection vehicle is to be economically suited for long haul.

Railroad Transportation

In an article entitled "Garbage Express Whistles 'Round the Bend" in the Washington Post on May 31, 1967, reference is made to a $178,000 study being made by the American Public Works Association to investigate the feasibility of remote landfills using railroad transportation. In the New York Times, on May 7, 1967, acting County Executive James C. Harding is quoted as stating that Westchester County is "giving more consideration . . . than to any other one" to a plan to ship large bundles of compacted garbage out of Westchester by train to locations beyond Albany. He also indicates that San Francisco and other cities are studying similar plans; a 450 mile haul distance is being considered for San Francisco.

The Westchester proposal dated February 2,

[5] "Transfer Operations," F. R. Bowerman, Proc. National Conference on Solid Waste Research, APWA, Dec., 1963.

[6] "The Orange County Refuse Disposal Program," Santa Ana, Orange County Road Department, California, 1965.

[7] See reference 2.

[8] "Municipal Refuse Collection and Disposal," Office for Local Government, State of New York, September, 1964.

[9] "Equipment Development," Otto Kuehn, Proc. National Conference on Solid Waste Research, APWA, Dec., 1963.

[10] Oral communication from M. M. Feldman, Deputy Commissioner, Dept. of Sanitation, New York to A. S. Goodman, May 4, 1967.

1967 was furnished and discussed with one of the authors of this report by the New York Central system.[11]

The New York Central has indicated that it has been studying the potential of transporting solid wastes to remote landfills for about 2½ years. They have reviewed the possibilities for 76 major cities in their system and have developed concepts of handling with equipment manufacturers and sanitary landfill contractors. Among locations in Massachusetts, the Boston and Springfield areas were indicated as possible sources of material. The B & M and New Haven railroads have contacted the New York Central concerning possible operations in Massachusetts.

Features of general interest are:

1. Unit costs go down with increased tonnages, because longer trains can be used with essentially the same motive power.
2. With railroad equipment and landfills, all solid wastes including demolition material can be handled.
3. More than one route is normally available to a disposal site. The railroad claims that this is an advantage over truck transportation in bad weather.
4. The railroad states that in the event of work stoppages, supervisory personnel can handle trains until an injunction is obtained on the basis of danger to the public health.
5. The railroad estimates that within about 27 miles haul distance to a landfill site, the railroad operation is probably not competitive with trucks.
6. The railroad does not handle the landfill operation. This is done by another contractor, the railroad and the contractor submitting a joint proposal.

The New York Central proposal to Westchester was a firm bid, with respect to rail rates per ton and landfill rates per ton at a location about 150 miles from New York City. The landfill rate is $1.50 per ton and the rail rate would be $2.15 to $2.75 per ton depending upon the minimum daily tonnage (1000 to 3000 tons) and the number (1, 2, or 3) and location of transfer stations at railroad sites in Westchester. The railroad would supply the flat cars, motive power, and crews. The County would own and operate the transfer stations and containers receiving the refuse from collection vehicles at costs estimated at $0.40 to $0.77 per ton for transfer stations and $0.31 per ton for containers. The total cost to the County is estimated accordingly at $4.36 to $5.06 per ton for transfer, rail transportation, and landfill.

Water Transportation

Barges, scows, lighters and special freight boats are used to transfer refuse from collection vehicles to disposal plants, land dumps, or water dumps. Usually the vessels are towed by tug boats, but some are self-propelling. The use of this method of transportation is now limited to transfer operations. A major operation of this type is in New York City where over 200,000 tons per month of refuse and residue from incinerators is hauled an average of 20 water miles for disposal in the Fresh Kills landfill in Staten Island. In this operation,[12] the transfer from land to boat is made at a cost of $0.62 per ton, the water transport is made at a cost of about $0.05 per ton-mile, and the Fresh Kills landfill costs $1.26 per ton, for a total cost of $2.85 per ton not including capital charges.

This landfill operation by New York City does not require a major transfer at Fresh Kills. As discussed in the APWA manual,[13] when refuse is transported by water to landfills, it is necessary to transfer the material twice, once from the collection vehicle to the boats and again at the disposal site from the boats to trucks or trailers for transport to the point of dumping. The extra cost involved in such operations is a major reason why water transportation of refuse has decreased considerably in recent years.

At one time, it was not uncommon to dump untreated refuse at sea. Boston and New York both engaged in this practice until about 1930. This is no longer practiced in the United States because of potential beach pollution resulting in prohibition of the practice by the courts, and the unfavorable economics of the haul operation.

Some four years ago, Prof. Leslie Silverman of the Harvard University School of Public Health[14] started to investigate the possibilities of placing incinerators on available ship hulls such as the World War I and II Liberty or Victory ships (7,000 to 10,000 tons displacement). A comprehensive study has been underway under a Public Health Service grant for the past two years at Harvard, under the direction of Prof. Melvin First[15]

[11] Discussions between Michael O. Albl, N. Y. Central R. R. and A. S. Goodman on May 25, 1959.

[12] "Statistical Review and Progress Report for March, 1967," N. Y. City Dept. of Sanitation.

[13] See reference 1.

[14] "Incineration of Solid Wastes at Sea," Leslie Silverman, APWA Reporter, July, 1964.

[15] Discussions with A. S. Goodman and J. J. Cochrane, June 5, 1967.

and a progress report is being prepared for release in a few months. The operation would be aimed principally at handling refuse delivered to coastal transfer stations in Boston. The Silverman study indicated a transfer station cost of about $0.50 per ton. The Harvard research is discussed further in other chapters.

Another water transport operation carried on in the Boston area is the burning of waste materials, primarily demolition lumber, by the Boston Marine Disposal Corp., aboard barges having a capacity of 1800 tons. The residue is sold for fill material.

Potential of Long-Haul and Special Transportation Methods

As we tend to become more urbanized, the increased population not only produces more refuse but a scarcity of land suitable for sanitary landfill develops. When this occurs, we can either conserve the remaining urban area allocated to landfill by reducing the volume by incineration, or we can look for landfills in locations more distant from collection centers. It is possible to apply engineering logic and make studies of cost and practical considerations of the alternatives, using sophisticated methods of systems analysis if we wish, to arrive at a recommended plan.

From the standpoints of conservation, recreation, and other activities for which we find it difficult to estimate a definite dollar value and simply for the development of additional useful land for future use of our increasing population, it may be appropriate for the Commonwealth to subsidize landfill operations in many locations. In our opinion, a comprehensive study and a broad outlook on the potential of landfills may yield some very significant conclusions. We recommend that the Department of Natural Resources and/or other interested agency make a land study of a major portion of the state to evaluate the possibilities of using long-haul transportation for the development of remote landfills and the possibilities of land and water transportation for the development of seacoast landfills, while reserving currently available urban and suburban land for other purposes.

Chapter IV

SOLID WASTE TREATMENT

Introduction

In the preceding chapter, collection and transportation of solid wastes were discussed. The next step would consist of either separation and/or treatment to change the form of the solid waste, followed by ultimate disposal to land, air or water. Treatment is only one phase of the final disposal of solid waste. We have chosen to use separate chapters in this report to emphasize this fact.

Each community has its own variation in composition of solid waste. The analysis of the waste provides part of the information required to determine what types of treatment are suitable. Table 3 indicates the function of each technique of solid waste treatment.

This Chapter will concentrate primarily on incineration and composting. Details, including the advantages and disadvantages of other methods of treatment, can be found in an excellent publication by the American Public Works Association entitled "Municipal Refuse Disposal."

TABLE 3

Solid Waste Treatment Methods

Type of Treatment	Results: Altering Form Which Requires Additional Handling	Results: Complete Disposal
Open Dumping		X [1]
Sanitary Landfill		X
Incineration (Central)	X	
Composting	X	X [2]
Feeding food waste to swine	X	X
Grinding of food waste	X	X [3]
Salvage and reclamation	X	
Disposal at sea	X	X

[1] Unacceptable because of subsequent environmental deterioration.

[2] Only if end product is sold commercially.

[3] Additional capacity must be provided at waste-water treatment plant.

Incineration

General

Incineration of solid waste is a treatment method which has been used for many years with varying degrees of success. Its objectives are a volume reduction to conserve land available for final disposal and the stabilization of organic material to provide for nuisance-free final disposal. The term "incinerator" in this discussion will mean a central type operated by a municipality or private company as opposed to a home type burning device. Any reference to other than central will be so noted.

An incinerator is a treatment plant composed of the following components: weighing scale to determine the quantity of refuse, storage bin to equalize loads to the furnace, crane with lifting device to charge the furnace, a furnace with required combustion air to burn solids, combustion chamber to burn gases, non-incinerable residue removal facilities, and fly ash removal facilities. A schematic diagram of a typical incinerator is given in Figure 2. This package requires a considerable investment by a community and a skilled crew to satisfactorily operate and maintain it. The capital cost and annual operating costs are a function of the capacity, generally decreasing in terms of unit cost with increasing capacity. A range of $3,000 to $8,000 per daily ton is reasonable for a capital investment with operation of maintenance costs of $3.00 to $5.00 per ton. The Braintree incinerator currently being designed by Camp, Dresser and McKee[1] has the following estimated cost:

Construction Costs (240 tons/day)	$1,750,000
Construction Costs per ton of design capacity	$7,300
Cost of refuse disposal (including amortization of plant and operating costs)	$5.75/ton

[1] Camp, Dresser & McKee, "Town of Braintree, Massachusetts, Report on Refuse Disposal," October, 1966.

The most economical site for a disposal area is one as close as possible to the population area with sufficient volume to operate it as a sanitary landfill at a cost of $1 to $2 per ton. Haul costs by truck to remote landfill sites can increase the cost by several dollars per ton. It has been estimated for New York[2] that a 5-mile haul costs approximately $1.70 per ton and a 20-mile haul costs approximately $3.30 per ton, using collection vehicles. California experience, as discussed in the preceding chapter, indicates a cost of 11.4 cents per ton-mile. When the combined haul and landfill operation reaches the $5 per ton level, the use of a method such as incineration becomes economical. Figure 3, Effect of Incineration on Volume, shows the land conservation which can be accomplished using incineration. Frequently, incinerators are constructed at an existing landfill site to reduce the volume of refuse to be disposed of by 1/3 to 1/10 of the original volume. The net result is to increase the useful life of the site by a factor of 3 to 10. As previously noted the haul distances to incinerators must be short to compete with landfills which often means locating the operation in a built up section of the community.

In the elimination of solid waste by incineration, the possibilities are introduced of air, water and land pollution. An effective waste management program must consider the entire air, water, land complex together, and not as separate problems. Figure 3 indicates the approximate amount of residue which must still be disposed of on land. If burning is not complete, which frequently has happened in the past, groundwater contamination can occur. Another in plant function which has a potential for water contamination is spray removal of fly ash introducing both particulate and thermal pollution.

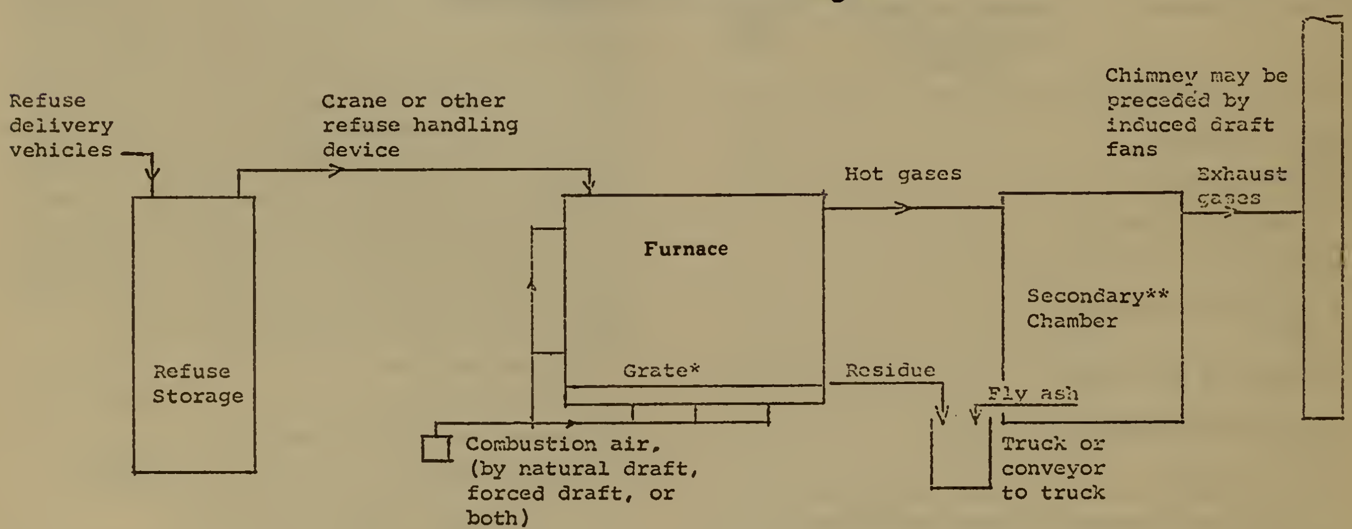
Air Pollution Considerations

Air pollution control has a profound effect on the economics of solid waste treatment by incineration. Gaseous emissions to the atmosphere from incinerator operations can be classified in three groups: (1) odorous organic compounds, (2) particulate matter, and (3) inorganic oxides. Organic discharges are controlled in incinerator design by operating at a minimum of 1400°F insuring complete organic combustion. Present requirements for fly ash removal standard can be met using water sprays and impingement baffles. It is expected, however, that more stringent air pollution controls will be adopted in the near future which will decrease the allowable particulate emissions by a factor of four. This level of discharge cannot be met with the conventional methods. Sophisticated and costly devices such as electrostatic precipitators will be required to reduce the emissions to an acceptable level. Modern fly ash collection equipment for a community of 100,000 to 200,000

[2] "Municipal Refuse Collection and Disposal," State Office for Local Government, Sept., 1964, New York State.

FIGURE 2

Incinerator Schematic Diagram



* Grate may be level, inclined, circular, rotating, fixed, movable or any combination of these.

**Secondary chamber may be one or more enclosures used for combustion fly ash settlement, gas cooling, fly ash collection, or a combination of these functions.

population adds $500,000 to the cost of the incinerator.[3] We recommend that any economic study of solid waste disposal by incineration include the costs of high efficiency fly ash removal equipment even if, at the present time, it is not required to meet today's standards.

The third atmospheric pollutant, inorganic gases, continues to be discharged even with first class particulate removal equipment and high temperature combustion. The major component of this discharge is carbon dioxide with lesser amounts of hydrogen chloride and oxides of sulfur and nitrogen. Of these compounds, carbon dioxide and oxides of nitrogen cannot be removed economically from the flue gas. These air pollutants are removed from the local environment by tall stacks which discharge them high into the earth's atmosphere. The question which remains unanswered at this time is what will be the long range (hundreds of years) effect of the unnatural increase in these components in man's atmosphere?

Waste Heat Utilization

American refuse has an estimated total heat energy of 4500 B.T.U. (British Thermal Units) per pound.[4] During incineration latent heat for burning and losses requires about 55% of the total, leaving 45% available. In most cases this excess heat is wasted through the exhaust stacks. Many incinerators in Europe and some in the United States now make use of this waste heat. In Europe, waste heat is used to produce steam at a rate of approximately 1.4 pounds per pound of refuse burned. However, factors such as high fossil fuel costs, lower labor costs, short supply of other fuels, existing steam distribution systems and municipal ownership of power generating stations in Europe make direct economic comparisons with American practice unrealistic. In the United States in 1965 there were three successful steam generating plants in Atlanta, Miami and Oceanside, New York.

The uses of waste heat for the production of steam and/or power are as follows:

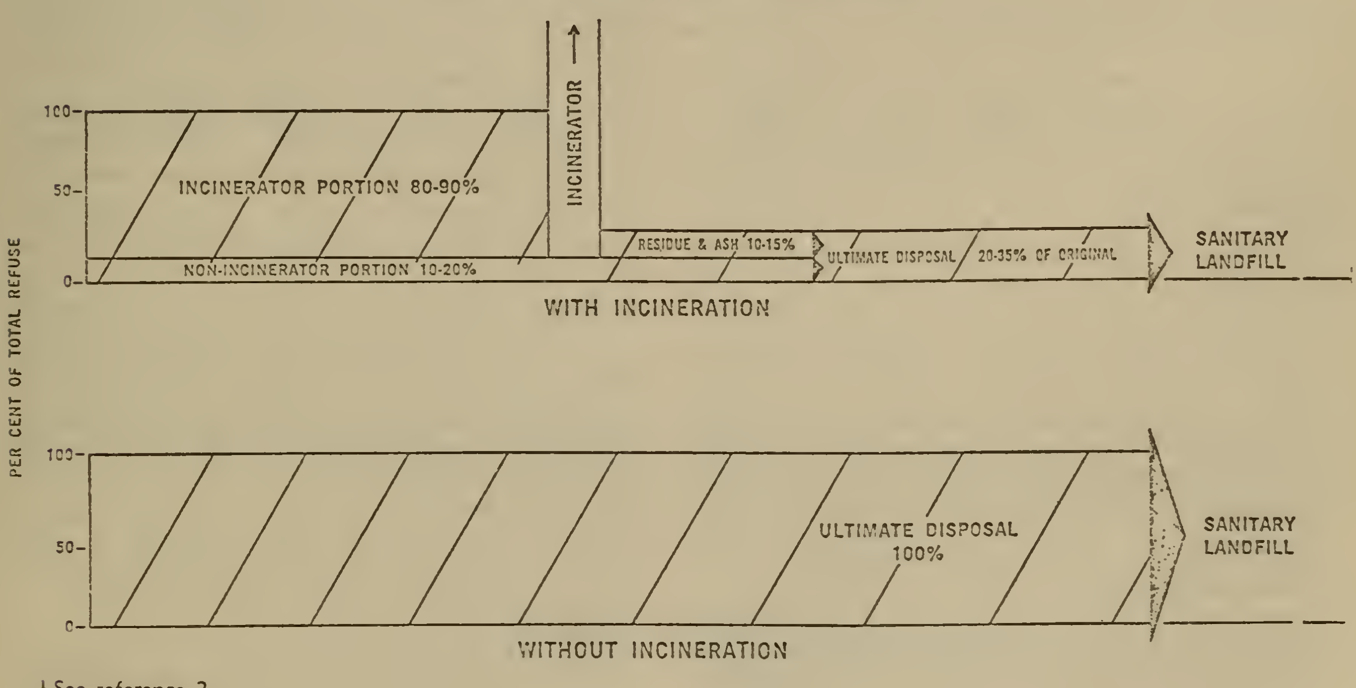
1. In plant uses such as for electricity or heating.
2. Sale to a public utility for distribution.
3. Sale to local industry.
4. Provide power for grinders and shredders.

[3]First, Melvin W., "Urban Solid-Waste Management," New England Journal of Medicine, Dec. 29, 1966, p. 1482.

[4]Rogus, Casimir A., "Control of Air Pollution and Waste Heat Recovery from Incineration," Public Works Magazine, June, 1966.

FIGURE 3

Effect of Incineration on Volume[1]



[1] See reference 2.

5. Desalinization of sea or brackish water.

6. Wastewater (sewage) treatment.

7. Pre-dry refuse to get a better burn.

8. Dry sewage solids to be subsequently incinerated.

9. Reduce air pollution equipment costs by reducing temperature and volumes of exhaust gases.

Associated with the development of uses of waste heat there are disadvantages and problems which include the following:

1. For the reliable sale of steam and/or power
   a. provide standby auxiliary fuel, or
   b. operate plant on a 24 hour per day, 7 day per week basis, or
   c. provide energy only when available and at a variable quantity.
2. Buyer must be near the plant because long transmission lines destroy the economic advantage.
3. Provide extra capacity because it is necessary to shut down furnaces for maintenance and repairs.
4. Power requirements at the plant alone are not great enough to justify the additional capital investment.
5. In many areas the power rates are so low that, even with free fuel, the additional expenses involved still favor the normal means of power production.
6. Boilers and appurtenances required to generate steam require licensed operators which increase labor costs.

A factor which is making waste heat recovery more attractive is the increased quality of flue gas effluent desired. Waterwall furnaces are used for a system which will utilize waste heat. A recent engineering study by Metcalf and Eddy[5] indicated an overall savings for a large (500 tons/day) incinerator even with the increased cost of the waterwalls. Two refuse burning systems were compared with identical stokers, one with waterwalls and electrostatic precipitator. the other containing refractory walls, spray chamber and precipitator. The waterwall design had an estimated construction cost of $200,000 higher but the total cost per ton burned was $0.36 less. This indicates that even

[5]Personal communication from James Fife, Senior Associate, Metcalf & Eddy, Boston, Massachusetts, May 12, 1967.

TABLE 4
Waste Heat Utilization[1]

	Plants Reporting Use	Number of Plants Using Heat For:								
					Steam Production					
		Bldg. heat and/or Hot Water	Electric Power	Sewage Sludge Drying	For Sale	Outside Heating	Other Use	Use Not Stated	Preheat Combustion Air	Other Use
1945-1950	2	1	1	0	0	0	0	0	0	0
1951-1955	10[a]	4	2	2	1	0	0	2	1	0
1956-1960	17[b]	10	1	3	0	1	d, g	1	1	e, f
1961 to date	14[c]	9	1	1	1	1	h	1	0	i
Totals	43	24	5	6	2	2	3	4	2	3

[a] One plant reports building heat, hot water, and preheating combustion air. Another reports building heat and sludge drying.
[b] One plant each report: hot water and power generation; hot water and air preheating; hot water and sludge drying; and steam for equipment drives and heating nearby hospital.
[c] One plant reports building heat and steam for sale. One reports power generation and desalination.
[d] Equipment drives.
[e] Sludge furnace.
[f] Heat for sludge digester.
[g] For sewage treatment plant.
[h] Desalination of sea water.
[i] Tubular gas reheater cools combustion-chamber outlet gas and reheats scrubber exit gas.

[1] Proceedings of the 1966 National Incinerator Conference, ASME, New York, May 1-4, 1966, p. 15.

if the waste heat is not used subsequently for steam or power, it would still be an advantage to use the waterwall type of design. The reason for this is the savings in air pollution equipment realized by reducing the temperature and volume of the gas to be cleaned. As the plant size decreases, the cost advantage is reversed. The break even point is at about 250-300 tons per day capacity. The conclusion which can be reached by this information is that stricter air pollution controls are making waste heat utilization more economically feasible in the United States. A survey was conducted by the ASME[6] for presentation at the 1966 National Incinerator Conference which indicates United States practice in waste heat utilization. The total number of installations reporting was 205 with 43 using waste heat. Table 4, Waste Heat Utilization, gives a breakdown of the applications.

It can be concluded that most plants discharge the waste heat to the atmosphere unused. The plants which use the excess, do so for variety of different purposes.

There are three examples of recent United States incinerators designed for major waste heat utilization which are discussed in this section.

South Bay Incinerator, Boston, Massachusetts—This plant was designed to use waste heat for generation of electricity and steam heat for the Boston City Hospital. Three drum tubular convection type boilers with a total capacity of 225,000 pounds of steam at 250 psig and 600°F per hour are used for waste heat recovery. The boilers were designed to operate at higher temperatures than available. There were problems encountered with the furnaces and the air control resulting in low operating temperatures. Also contributing to the low temperatures experienced was the low calorific value of the refuse. An economic evaluation was conducted and it was decided that the production of steam using the existing hospital boiler was more favorable. Therefore, the use of the waste heat recovery equipment was discontinued. This example serves to indicate the problems which can be encountered in this type of venture.

Oceanside Incinerator, Hempstead, New York—This plant has two 300 tons per day incinerator units and one rated at 150 tons per day. Waste heat is recovered by two convection type boilers on the larger furnaces. Each boiler has a rated capacity of 85,000 pounds of steam per hour at 462°F and 460 psig. Steam from the boilers drives two 1250 kw turbine generators to produce electricity for the plant itself. Some steam is also used for evaporators which are cooled with sea water and subsequently cooled to produce fresh water. The desalinization capacity of each evaporator is 115,200 gallons per day and the water produced is used for boiler makeup and fly ash removal spray. This is the first incinerator to treat sea water and realizes a savings by not having to develop another source such as wells which would be difficult in this coastal location. We understand they are experiencing some difficulties with the operation of the plant, but were unable to obtain the details.

Navy Yard Incinerator, Norfolk, Virginia—This plant is a modern plant with two waterwalled furnaces each with 180 tons per day capacity. The plant has just been put into service. It is designed to produce 50,000 pounds of steam per hour or 3.3 pounds per pound of refuse. An oil burner auxiliary unit was included to insure a continuous supply of steam even with an interruption of refuse. Both the base installation and the vessels in dock use the steam. At this early stage, the plant appears to be operating quite successfully and the Navy plans to go ahead with three more incinerators of the same type.

We recommend further study in two areas of waste heat utilization which could lead to considerable savings in disposal costs throughout the Commonwealth. The first proposal concerns the sale of steam generated by refuse burning. Conditions such as existing steam distribution mains or concentration of industry near the incinerator would be prerequisites to this activity. With the latter conditions prevailing we would recommend that a consulting engineering firm make an engineering study to evaluate the economics.

Concerning the sale of steam, there are several possibilities and problems involved. We recommend an engineering feasibility study which would examine the additional cost of steam production equipment for a modern waterwalled incinerator with a determination of the cost per pound of steam for a typical installation. This steam could then be sold to an existing utility for distribution or for conversion to electric power, providing it was economically sound. An alternative which should be examined is the sale of refuse for use as fuel to a steam or power utility. Fuel cost for steam in the Boston area is approximately $0.50 per 1000 pounds.[7] Discussions with municipal officials, consulting engineers and utility personnel lead us to the conclusion that the major problem involved in the sale of waste heat in any form is the past history of unreliable municipal opera-

[6]Proceedings of the 1966 National Incinerator Conference, ASME, New York, May 1-4, 1966, p. 15.

[7]Personal communication with Mr. Frank C. Meyer, Boston Edison.

tions of all types. It is our opinion that this is not an insurmountable problem if some form of joint operation is feasible at a plant designed to utilize waste heat. These possibilities would be investigated in a feasibility study of the proposal. Our preliminary calculations indicate that $1.00 to $1.50 per ton revenue could be realized by steam sale, which represents a direct reduction in the disposal costs.

The second waste heat proposal for which we recommend further study is power production for other municipal services. Successful results from a study such as this would find application in many of the communities in the Commonwealth. The treatment plant would be multi-purpose including solid waste disposal, wastewater (sewage) treatment and water treatment with each producing products or providing energy required by the other. The interrelationships would include power production from incineration for operation of equipment (pumps, sludge collectors, chemical feeders, etc.) for both water and wastewater treatment. In turn, the water treatment plant would produce, in addition to the municipal requirements, boiler make-up water. The sewage sludge would be pre-dried and disposed of by incineration. Another possibility is the use of fly ash as a coagulant aid for both water and waste treatment. This would be quite a complex treatment plant which would require a detailed engineering and economic feasibility study. Today's treatment plants are plagued with high labor costs. A multi-purpose plant of this type would result in a substantial reduction in the number of personnel, as compared with the number needed for three individual plants.

Current Development in Incinerators

A high temperature incinerator (Melt-zit) pilot plant is in operation in Whitman, Massachusetts. Its major advantage over conventional incineration is the final product which is a granular material with a volume of 1-2% of the input volume. The incinerator is without grates, operating on the open hearth principle at a temperature of 3000°F. At these temperatures, metals are melted and subsequently quenched with water to form small pellets. The costs estimates are based on only this one pilot plant with very limited actual operation time. It now appears that both the construction cost and operating cost would be somewhat higher than conventional incineration. We are of the opinion that more testing must be done before this type of incinerator could be widely used. To date the unit has not been run on a continuous basis; therefore, some problems surely remain to be uncovered and the associated operating cost need be determined. Operation will require more highly skilled labor than a conventional incinerator and may lead to municipal operational problems. Another major area which needs data is that of air pollution. No stack tests have been made as of yet. This is a particularly critical part of the operation because at a higher temperature more metallic oxides will be produced. After successful completion of the pilot operation, a unit of this type could have application in the Commonwealth where shortages of land for residue exists.

Several other modifications of the burning units have been proposed. An example of one is an incinerator designed by A. D. Little[8] which has a circular, air cooled wall furnace and can be constructed outdoors saving the expense of any enclosure. Another modification of the conventional incinerator design was a tangential overfire technique.[9] This proposal, which is in the development stage, indicates a more complete burn is possible with a much cleaner exhaust gas.

It is expected that many improvements will be developed in American incinerator designs because of the increased interest in this major engineering problem. This work should result in less costly, more reliable and more efficient incinerators in the future.

Incineration-at-Sea

Sea based incineration currently being investigated at Harvard University will be discussed in detail in the next chapter because it is not the incineration but the disposal technique which is novel. Basically the same type of incinerator can be used in a ship as on land, provided that the unit does not require major modification of the vessel.

Composting

General

Treatment of solid wastes by composting is a bio-chemical process which degrades the organic material to produce a humus like end product. Early attempts at this method were unenclosed plants which practiced separation of the inert material for subsequent salvage. These plants were plagued with nuisance complaints and high costs. The next step in the development was the mechanical enclosed plant which allowed for more

[8]Proceedings of the National Incinerator Conference, ASME, New York, May 1-4, 1966, p. 15.

[9]Weintraub, M., et al., "Experimental Studies of Incineration in a Cylindrical Combustion Chamber" Bureau of Mines Report number 6908.

control of the oxygen supplied, temperature and moisture. Since separation was still required and usually done out-of-doors adjacent to the plant, there was no improvement in the nuisance potential. A modern type installation which is now (1967) in the pilot plant stage was developed by Varro.[10] The major improvements in this process include the use of grinding to provide for the acceptance of all municipal refuse (with a few exceptions due to extreme size) and the addition of standard nutrients so that the final product can be registered and labeled as an "organic fertilizer." This addition increases the market value over the conventional product which can be used only as a soil conditioner.

History

There is a lack of confidence in composting in the United States, mainly because of an extensive past history of failure. Major reasons for this poor record include a decrease in revenue from salvage of non-compostable material, poor or non-existent market for compost and nuisance conditions. Many of the United States plants were small (less than 100T/d—Tons per day). After a considerable amount of research work a 100T/d plant was constructed in McKeesport, Pennsylvania in cooperation with the U. S. Public Health Service by the Compost Corporation of America. It was closed after approximately one year of operation in 1956. Table 5 summarizes the status of composting plants in the United States.

[10]Varrow, Stephan, "Engineering Aspects of Composting," Seminar on Advanced Solid Waste Collection and Disposal, Rutgers State University.

The Largo, Florida plant which is serving as a model for a new 300T/d plant in Houston, Texas is an unenclosed, mechanized plant producing a fortified compost. The city fee for disposal at this commercial plant is $3.50 per ton of refuse.

Europe has had better experience with composting than the United States. There are several logical reasons for this which include a different market available for the compost, different labor costs, and a government subsidy of many of the plants. Refuse collection practices in the United States also differ from those in Europe where the total amount of compostable material is greater. For the above reasons one cannot equate treatment by composting of solid waste in each country. In both Europe and Asia, all the large scale composting plants are financed by the government for very specific purposes. In Holland the government is using the compost to condition the thousands of square miles reclaimed from the sea. The govern-

TABLE 5
Municipal Solid Waste Composting Plants in the United States[1]

Location	Company	Process	Capacity Ton/Day	Began Operation	1965 Status
Altoona, Pennsylvania	Altoona FAM, Inc., Fairfield Engg. Co.	Fairfield-Hardy	45	1951 1963[a]	Operating
Largo, Florida	Penninsular Organics, Inc. National Composters Co.	Penninsular Organics	50	1963	Operating
Norman, Oklahoma	International Disposal Corp.	Naturizer	35	1959	Closed 1964
Phoenix, Arizona	Arizona Biochemical Co.	Dano	300[b]	1963	Closed 1963[c]
Sacramento Co., Calif.	Dano of America, Inc.	Dano	40	1956	Closed 1963
San Fernando, Calif.	International Disposal Corp.	Naturizer	70	1963[d]	Closed 1964
Springfield, Mass.	Springfield Organic Fertilizer Co.	Frazer-Eweson	20	1954[e]	Closed 1962
Williamston, Mich.	City of Williamston	Riker	4	1955	Closed 1962
Wilmington, Ohio	Good Riddance, Inc.	Windrow	20	1963	Operating

[a] Date of initial operation of the original Hardy plant is unknown; plant rebuilt in 1963.
[b] According to European Dano practice, the plant capacity is about 175 T/day.
[c] Reported to be back in limited operation, March, 1965.
[d] Date of initial operation is unknown; continuous operation began in July 1963.
[e] Partially burned in 1958; rebuilt in 1961.
NOTE: New plants are being operated, constructed or planned in such U.S. cities as St. Petersburg, Florida; Mobile, Alabama; Houston, Texas, and some others.

[1] Wiley, J. S. and Kochtitzky. O. W., "Composting Developments in the United States," Compost Science, 6:2:5, 1967.

ment distributes compost in the interest of agricultural development in Thailand, Japan, Egypt and Korea.

In Europe sewage sludge is added to refuse to increase the fertilizer value and in some cases the composting is justified more for sludge disposal than for refuse treatment.

Costs

Since the sale of compost is a commercial venture, operation of a plant by a municipality would in most cases be undesirable. The normal procedure would be to have an industrial company invest the capital for construction of the plant and charge a per ton rate for disposal of the municipal refuse. Assuming that insufficient land is available for the operation of the least expensive sanitary landfill, the choice would then be between an incinerator and composting. Using the approximate incineration cost per ton figures from the MAPC report for a 600T/d capacity, the compost disposal charge for a community would need to be approximately $5.00 per ton or less to compete economically. Operating costs including amortization for a composting plant in the United States would vary between $12-$16 per ton of compost produced. Each ton of compost produced requires the input of approximately two tons of domestic refuse.

The following example illustrates the economic considerations involved. Assume a disposal fee for a community of $4.00 per ton; revenue would then be $8.00 per ton of compost produced. With production costs at say $15.00 per ton, the resultant cost of production would be $7.00 per ton. The actual selling price would then have to be greater to include delivery to the consumer and provide for a profit on the capital invested in the plant. For illustrative purposes, assume a selling price of $8.50 per ton. To make this treatment suitable for a Massachusetts community we must find a continuing nearby market for this product at the $8.50 per ton price. This is uneconomical because it is possible to buy humus (which is approximately equivalent to compost) for about $6.00 per ton delivered in bulk.

The market value for compost can be improved by adding phosphorous, nitrogen and potassium in sufficient quantities to produce an organic fertilizer. The incremental costs per ton must be added for the grade desired. If a market can be found for the enriched compost then composting would be a suitable method of solid waste disposal. Varro notes the desired physical properties of the final product such as granular, free flowing, proper moisture content which must meet the standards of presently marketed organic fertilizers.

Conclusions

There are several distinct advantages to composting as a treatment and disposal method in a solid waste system. The cost, assuming a suitable market, is comparable with incineration with a smaller residue. If fine grinding is used the non-compostable part of the refuse can be disposed of in a very small volume. A modern plant can be operated in a built up section of a community which serves to lower the collection costs by having short haul distances. Since there is no combustion, air pollution problems are avoided.

The major obstacle to composting is its product marketability. Farmers are the type of people who are reluctant to try an unproven product. This would then require the development of a market, possibly by selling at a loss in the initial stages. Enriched compost would seem to have some market value in Massachusetts but there is a question as to how much would be required. Soil conditioners such as humus are used in small quantities compared to commercial fertilizers. A change is now taking place in the application of fertilizer. In the past it was used mostly in a granular form. Today there is a strong trend toward a liquid form of fertilizer which has the advantage of a more uniform application and immediate penetration into the soil.

Since collection costs are generally several times greater than disposal costs per unit waste, some municipal officials express concern with private operation of disposal plants because it would be extremely costly if a private contractor shutdown for a major breakdown or curtailed the operation because of a changing market.

We are of the opinion that composting is not the solution to all solid waste treatment in Massachusetts but could have application in some communities. When considering a composting plant there are several important criteria. Since this is a biological process the composition of refuse is very critical. Not all municipal waste can be successfully composted. To compete economically, the site should be located in a central area and extreme care must be taken to protect the community from nuisances; this would include provisions for enclosed storage of non-compostable materials such as tires, mattresses, stones, etc. Engineering studies would be needed to prove conclusively that the cost is competitive with incineration. The most critical single factor is the market value of the final end product and this should be given a most scrupulous and detailed study.

Chapter V

SOLID WASTE FINAL DISPOSAL

Introduction

Refuse after collection and treatment if required is disposed of as a final step. This chapter will consider this final or ultimate disposal. The three locations in the environment for final disposal are land, air and water. Incineration is the vehicle when air is used and this was discussed in the preceding chapter.

Disposal on Land

Today, except for some isolated cases, nearly all solid waste finds its way eventually to the land. Therefore, it is important to face the problems associated with land disposal and plan carefully so that it will not interfere with future community development by inadequate planning. There are basically three terms which are used to describe land disposal techniques: (1) open dumping; (2) refuse filling; and (3) sanitary land filling. We will consider each of these three in order.

Open Dumping—Many communities in the Commonwealth still use open dumping for refuse disposal. This is a totally unacceptable method for municipal solid waste disposal. Continued operation of these facilities poses problems of public health and safety in addition to aesthetic undesirability. Open dumps act as reservoirs of disease by harboring carriers such as mosquitos, rodents and insects. Open burning is usually associated with these dumps, either by spontaneous combustion or purposely set, to reduce volume whereby extending the life of the dumps. Some disposal areas start out as sanitary landfills and through neglect or improper control, deteriorate into open dumps. We recommend legislation be enacted to require all open dumps to be immediately converted to and maintained as sanitary landfills. Legislation is not entirely sufficient but must be accompanied by a method to enforce it. We would suggest a series of steps beginning with a public information campaign including state condemnation of the public health hazard. If this was not successful, the next step would be a public hearing.

Exceptions which should require a special short time limit permit could be permitted for certain materials. Construction or other refuse which is *completely* non-putrescible could be open dumped provided the final surface configuration was such that all drainage was completely restored and there were no pockets for the collection of stagnant water.

Refuse Filling—This technique is used for land disposal of a material such as a completely burned incinerator residue. Compaction is obtained using earth moving equipment but sealing with an earth cover is not needed on a daily basis. This technique of refuse filling is for only special types of refuse and should not be used as an excuse for careless operation of a sanitary landfill.

Sanitary Landfill—This method of solid waste disposal is by far the least expensive of the acceptable techniques available presently. Sanitary landfilling was defined by the American Society of Civil Engineers[1] as "a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary." In general, a community with sufficient land resources should first consider the sanitary landfill for its solid waste disposal.

Depending on the site there are various operational procedures available. The end result is a disposal volume composed of cells of refuse approximately 8 feet deep with the area determined by the quantity of waste disposed of in a day. Cells are separated by earth used to seal each day's operation. One of the most important site criteria is the availability of cover material required for the daily cover and a final cover of 24 inches to prevent passage of rodents or emergence of insects. A typical landfill operation would include weighing facilities, earth moving equipment for cover material as well as for refuse compaction, an equipment enclosure area, and fencing to limit unauthorized access. The number of personnel required by this

[1]American Society of Civil Engineers Committee on Sanitary Landfill Practice, Sanitary Landfill, ASCE—Manuals of Engineering Practice, No. 39, N. Y., ASCE, 1959.

operation is considerably lower than for other disposal techniques, thereby keeping the annual cost at a minimum. The site need not be a strict fill type operation. On level ground a sanitary landfill can be accomplished by a cut and cover trenching operation. Properly run facilities have been located adjacent to residential areas with no problems whatsoever.

The operation as defined above is extremely simple and this is reflected in the unit costs. In Los Angeles, large sanitary landfills are operated in ravines outside the city limits. Costs reported by the Los Angeles County Sanitation District are $1 per ton[2] which includes the cost of land, access roads, weighing stations, and administration. New York City which also operates large landfills reported[3] a cost of approximately $1.20 per ton in 1960. A reasonable range of medium to small size landfill operations would be $1-$3 per ton in New England. The actual cost for a locality is so dependent on site conditions and availability of cover material that it is not realistic to use an average figure for all communities. A separate detailed cost estimate is required for each site.

[2] "Proceedings of the National Conference on Solid Waste Research," APWA, Dec., 1963.

[3] "Municipal Refuse Disposal," APWA, 1966, p. 349.

TABLE 6

Land Required for Ultimate Disposal[1]

Population Served	Sanitary Landfill Area[2] (Acres Per Year)	Incinerator Residue Area[3] (Acres per Year)
10,000	2.2	0 7
20,000	4.4	1.5
40,000	8.7	2.6
60,000	13.0	4 3
80,000	17.2	5.7
100,000	21.3	7.1
120,000	25.7	8.6

[1] Data from Municipal Refuse Collection & Disposal Office for Local Government, State of New York, Sept., 1964.

[2] Assume 8 foot average depth of compacted refuse estimated compaction of 50%.

[3] Assume ⅔ volume reduction (non-incinerable and residue).

Land availability is a critical problem in the Commonwealth. Table 6 indicates the approximate land required for both landfills and incinerator residual. Each community should take a hard look into the future to examine the effect of using large tracts of land for solid waste disposal.

The low cost at first glance may look quite attractive. This is true if the site is located within a reasonable distance from the collection route. Suitable areas are being used up with increasing speed forcing higher transportation costs which can tip the economic balance toward other methods of disposal. Municipalities in the Commonwealth are experiencing just such a situation. Examining the economics of remote landfills one finds that the collection costs are fixed as are the operation costs of the landfills. However, these are two possibilities for reducing costs, somehow lowering of the transportation costs and/or gaining revenue from land reclamation. Transportation cost reduction appears to have possibilities for the Commonwealth in the form of rail and sea transfer. These proposals are considered in Chapter III.

Properly designed and operated landfills can become valuable assets to a community or state, although there are some limitations on the use of these completed landfills. Many projects throughout the country could be cited as examples of land reclamation accomplished by solid waste disposal.

The following is a list of typical projects:

- Parks
- Playgrounds
- Golf Courses
- Parking Areas
- Airfield Improvements
- Light Industrial or Commercial Building
- Baseball Fields

Any of the aforementioned projects should be considered in local planning of refuse disposal. Careful planning for foundation locations would allow almost any kind of development to be constructed on landfills. However, because of potential problems with underground movement of gas and water, park type development is preferred in most areas over building construction.

The Commonwealth should consider major reclamation projects such as landfilling abandoned gravel pits, old granite quarries, swamps and marsh land, and coastal locations. These projects would represent an advantage in both land improvement and solid waste disposal. We, therefore,

recommend a state wide survey of all possible land reclamation projects. This would include expected useful life for each and costs associated with a nearby community's use of the site. Another important part of the report would be a benefit analysis after final completion of each project. This would aid in providing a more accurate economic evaluation of alternates between sanitary landfill operations and incinerators. Frequently, no improvement value is assigned to finished reclamation projects in this type of economic study.

In the past, human memory has been the record keeper for landfill operations. As land becomes more scarce, more extensive use will have to be made of former sanitary landfills. We recommend that some official agency be responsible for this record keeping which will be critical for the future development of the Commonwealth. This could be accomplished by adopting the following proposal. We recommend that all solid waste disposal sites be registered with the State Department of Public Health. As discussed in Chapter II, a plan should accompany this registration which indicates the extent of the site to be used and the final topography of the area.

Disposal at Sea

Disposal at sea has a poor past history. Years ago New York City practiced open dumping at sea to the detriment of the New Jersey shore, a practice which was ended with a Supreme Court edict. Today refuse is burned in Boston Harbor on barges and is meeting with adverse public reaction.[4] A quote by James Fox in a recent Boston Globe article notes part of the problem: "Nearby there are permanently moored barges—rubbish incinerators, without lights. The outer islands are infested with rats that come from those barges." Complaints are also voiced by officials from Hull and Winthrop concerning air pollution from odors, soot, and beach pollution from ash and floating debris. These existing conditions of disposal at sea are not acceptable.

The major advantage of sea disposal is the "unlimited" capacity to accept the refuse. The Federal Solid Waste Program is sponsoring a research project at Harvard University in connection with ocean disposal of refuse. This project is still in progress and will not be completed for several years. Initial results, however, are encouraging. The proposal is to use converted ships as floating incinerators which would not be ignited until the vessel was far enough out to sea to preclude any possibility of air pollution. The residue would then be discharged in predetermined dumping areas. Meteorological and biological studies are being conducted to investigate all possible problem areas before any large scale operation begins. Discussions with the project director, Dr. First,[5] indicates that the cost is estimated to be approximately the same as that for land based incineration. Of course the advantage would be in reduced air and land pollution. It is understood that investigations are sufficiently far along to consider a pilot plant operation. This project could be an excellent solution for coastal communities' problem of solid waste disposal and future developments along these lines should be observed very carefully.

[4] Boston Globe, Morning Edition, July 12, 1967.

[5] Personal communication, May, 1967.

Chapter VI

SYSTEMS ANALYSIS

Introduction

If we begin with a broad definition of systems analysis in solid wastes studies as an orderly and scientific approach to problem solving in this field, the term may be considered to include both the conventional planning methods which have been employed for many years by responsible civil and sanitary engineers and other environmental planners, and the more recently developed mathematical methods included in the discipline of "operations research."

Both the traditional and newer methodologies may be characterized by the following outline of steps encompassing a systematic approach:[1]

1. Definition of the system.
2. Description of the elements of the system and delineation to the fullest extent possible their interrelations and interactions.
3. Definition of system objectives.
4. Development of alternative approaches to system objectives.
5. Presentation of alternatives for achieving the system's objectives to the decision makers who select the best courses of action.

In accordance with the above we may consider the solid wastes collection system for a single truck shown by the verbal flowchart in Figure 4.

The picture of Figure 4 together with a map showing the geographic boundaries of the truck's service area would constitute Step (1). Among the components of Step (2) would be the types and quantities of refuse, and the alternatives which may be considered for collection frequency, pickup arrangements, types and sizes of collection vehicles, numbers of men per vehicle, street and highway routings, disposal locations and unloading facilities. Under Step (3), we might state that we wish to perform the garbage collection at minimum cost consistent with meeting legal, public health, and aesthetic specifications. Under traditional methods, the cost estimates of Step (4) would be limited to those for combinations which the planner judges by experience and intuition to be most likely to be suitable, while an operations research method would probably be able to value more of the possible combinations that are possible. If the minimum cost objective of Step (3) is firm and exclusive, it may be possible to develop a single system to present to the decision-makers under Step (5). In the more usual case, certain political judgments have to be made, and more than one solution could be presented by the planner to higher authority for a final decision.

If under either the traditional planning methods or operations research methods, the work is done skillfully and imaginatively, the search for alternatives will be thorough, there will be a concentration on goals and objectives, and there will be adequate consideration of feedback. The term "feedback" implies that examination of alterna-

FIGURE 4

Verbal Flowchart for Refuse Collection Truck

A—LEAVE GARAGE AND TRAVEL TO COLLECTION UNIT

↓

B—LOAD TRUCK

↓

C—TRAVEL TO TREATMENT OR DISPOSAL SITE

↓

D—DUMP LOAD

→ E—TRAVEL TO COLLECTION UNIT (→ A)

↓

F—GO TO GARAGE IF ASSIGNED COLLECTION UNITS HAVE BEEN SERVICED OR IF ASSIGNED WORKING HOURS HAVE BEEN COMPLETED.

[1] "Strategy for Michigan Water Resources Management: A Systems Approach," Technology Planning Center, Ann Arbor, Michigan, December, 1966.

tives provides new insights on the system and may suggest adoption of other technological techniques and objectives. Some operations research methods are designed to efficiently perform these functions of analysis.

Rational Method

The conventional planning approach to the design of a refuse collection and disposal system may be characterized by the term "rational." In such a design solution, local and regional data may be supplemented by published information on experience such as found in publications of the American Public Works Association,[2] the State of New York Office of Local Government,[3] and periodicals.

The rational approach to collection system design is described in a rather comprehensive study prepared at the University of California,[4] which also contains nomographs to reduce the arithmetic work involved. The efficiency of a collection system depends mainly on the judicious combination of the size of the collection vehicle, number of men per vehicle, the type of refuse pickup, and the number of trips per day for a given haul distance to the disposal site. An economic analysis is made of each of several collection systems. In the method, the collection cost is made up essentially of labor cost and vehicle operation cost.

The labor is subdivided into four unit operations:

1. pickup—net working time from pickup of first container until last container of refuse is loaded on collection vehicle.
2. haul—time for round trip to disposal site, from end of pickup period to the time vehicle returns to first container on a succeeding route, excluding time spent unloading or waiting at disposal site.
3. off-route—organized rest periods; time out for smoking, eating, refreshments, personal reasons, contacting residents and supervisors, and other miscellaneous activities.
4. at disposal site—waiting and unloading time.

For example, using an open truck manned by 3 men, a 16 mile round trip at an average haul speed of 20 mph, and with 3 trips per day per truck at 3 tons per trip, estimated overall manpower is 654 man-minutes per trip, or 218 man-minutes per ton. At a wage rate of $0.04 per man-minute, this corresponds to $8.72 per ton.

The equipment cost is comprised of interest on initial investment, depreciation, and operation and maintenance expense. For this case, the fixed charges at 4% annual interest for a $4000 truck with a 6-year life would be about $760 per year, and the operation and maintenance expense at $0.16 per mile for 936 trips of 20 miles each would be about $3000 per year. The total equipment cost per year of $3760 per truck corresponds to $1.35 per ton.

For the above hypothetical example, the total cost of collection would be $10.07 per ton, or say about $11.00 per ton including administrative costs. To this must be added the cost of disposal.

On a regional basis, it is believed that the Metropolitan Area Planning Council methodology in arriving at a recommended metropolitan Boston solid wastes program may be characterized to a large extent as having employed the rational method. Relations expressing unit cost versus capacity for various facilities, analytical studies of best transportation routes, map and field studies of sites, and other conventional means were used to investigate features of the design. Planners developed what they believed was a workable program taking into account engineering, economic. social, political, and legal considerations.

Operations Research Methods

In the past ten years approximately, the electronic digital computer has assumed an established role in most large civil and environmental engineering and planning organizations, as a tool to reduce the number of calculations that are made by hand and to enable the investigation of more alternative solutions for a specified problem than previously. For the most part, the computer has been used because these organizations have found it economically imperative as a labor-saving device and not particularly as a device for solving certain problems that could not be done practically by other means. There have been significant exceptions; for example, in the past five years, the computer has found application in the operation of reservoir systems; e. g., the many reservoirs in the Columbia River Basin are mathematically modeled and operated by a digital computer to maximize power production.[5] It is probably fair to

[2] "Refuse Collection Practice," APWA with assistance by Public Health Service, Public Administration Service, 1966. "Municipal Refuse Disposal," APWA, PAS, 1966.

[3] "Municipal Refuse Collection & Disposal," a guide for municipal officials.

[4] "An Analysis of Refuse Collection and Sanitary Landfill Disposal," Technical Bulletin No. 8, Series 37, U. of Calif. Sanitary Engineering Research Project, Dec., 1952.

[5] "Mathematical Methods in Water Resources Development Planning and Operations," L. A. Shoemaker, North Pacific Division, Corps of Engineers, U. S. Army, September 25, 1964.

state, however, that Federal defense and space agencies and supporting consultants, and industries and business have been more active in seeking out the advantages of operations research methods and employing them, than have the planners and operators of large-scale public works. This is not to deny that there has been a large amount of systems analysis research on problems of public works, education, welfare, etc. in the past half-dozen years or so;[6] however, for the most part, the work has been done within the academic community and has not been accepted by practicing engineers and planners or by public administrators. Except for the very limited use of such methods by the Bureau of Sanitation of the City of Los Angeles,[7] operations research to solve solid wastes problems is still in the developmental stage.

In our opinion, however, the situation will probably change in the near future. As the recently instituted Federal policy of setting budgets based on performance (comparison of costs versus benefits) replaces line-by-line justification of personnel and other components, mathematical systems analysis is bound to have a greater influence on decision-making. There are also such obvious advantages in formal systems analysis methodology in being able to develop more alternative solutions, in being able to focus on the variables of real importance, in being able to obtain optimum solutions, and in simply reducing the amount of technical manpower in routine tasks, that it seems likely that as persons now being trained in the techniques of operations research find their way into public and private organizations, such methodologies will find increasing use at all levels.

Before describing some operations research work going on in the solid wastes field which will probably find application in the planning and operation of actual projects, it appears appropriate to summarize the outstanding features of the two general types of models used in systems analysis—simulation models and analytic models. In this connection, a recent article by Dorfman[8] contains a discussion which, although not having to do with solid wastes planning, is an excellent review of the differences between models.

In investigations such as those carried out by the Harvard Water Program,[9] probably the outstanding pioneering example of comprehensive operations research studies for public works, the laboriousness of engineering calculations was reduced and it was possible to apply economic theories of resource application, statistical theories, and decision-making under conditions of uncertainty.

In simulation models, the planner defines the variables and the interrelationships and sets them down in appropriate time sequences. The consequences (output) of any set of assumptions for variables (input) may be determined. In analytic models, there are a series of equations relating the variables and a group of constraints which limit the solutions within certain ranges of values.

With the simulation model, an optimum solution is obtained by running a number of trials and converging on appropriate values of design variables. With the analytic model, standard methods of calculus or linear or dynamic programming or other mathematical techniques are used to arrive at optimal values of design variables. The most serious difficulty with simulation models is that they can be extremely large and can involve an undue number of trials to yield acceptable answers; this often makes the simulation concept impractical unless the model can be simplified (for example, if there are x major design variables, each with y values, a complete investigation can involve y^x simulations). With analytic models, time streams must be converted to present values before processing and certain compromises are often made to develop the relationships into a form susceptible to mathematical manipulation. The analytic models also have the disadvantage of not usually being able to handle probabilistic complications.

Dorfman suggests that analytic models and the simulation approach be employed in tandem. First, the problem can be schematized into a set of manageable mathematical relationships that can be solved for an approximation to a good or optimal design, then a range of plausible variation around that tentative solution can be explored by a sequence of simulations. In this way the strengths of each method can be used to compensate for the weaknesses of the other.

One of the authors[10] of this report has found that it is possible to develop a simulation model which also has an optimizing routine associated with it. The methodology was developed for study-

[6] "Operations Research for Public Systems," MIT Course, Sept. 5-9, 1967.

[7] Discussion of paper, "Simulation and Analysis of a Refuse Collection System," J. M. Betz and R. P. Stearns, Journ. San. Eng. Div., Proc. ASCE, Paper 4830, SA3, June, 1966.

[8] "Formal Models in the Design of Water Resource Systems," Robert Dorfman, Water Resources Research, Vol. 1, No. 3, 1965.

[9] "Design of Water-Resource Systems," A. Maass, et al., Harvard University Press, 1962.

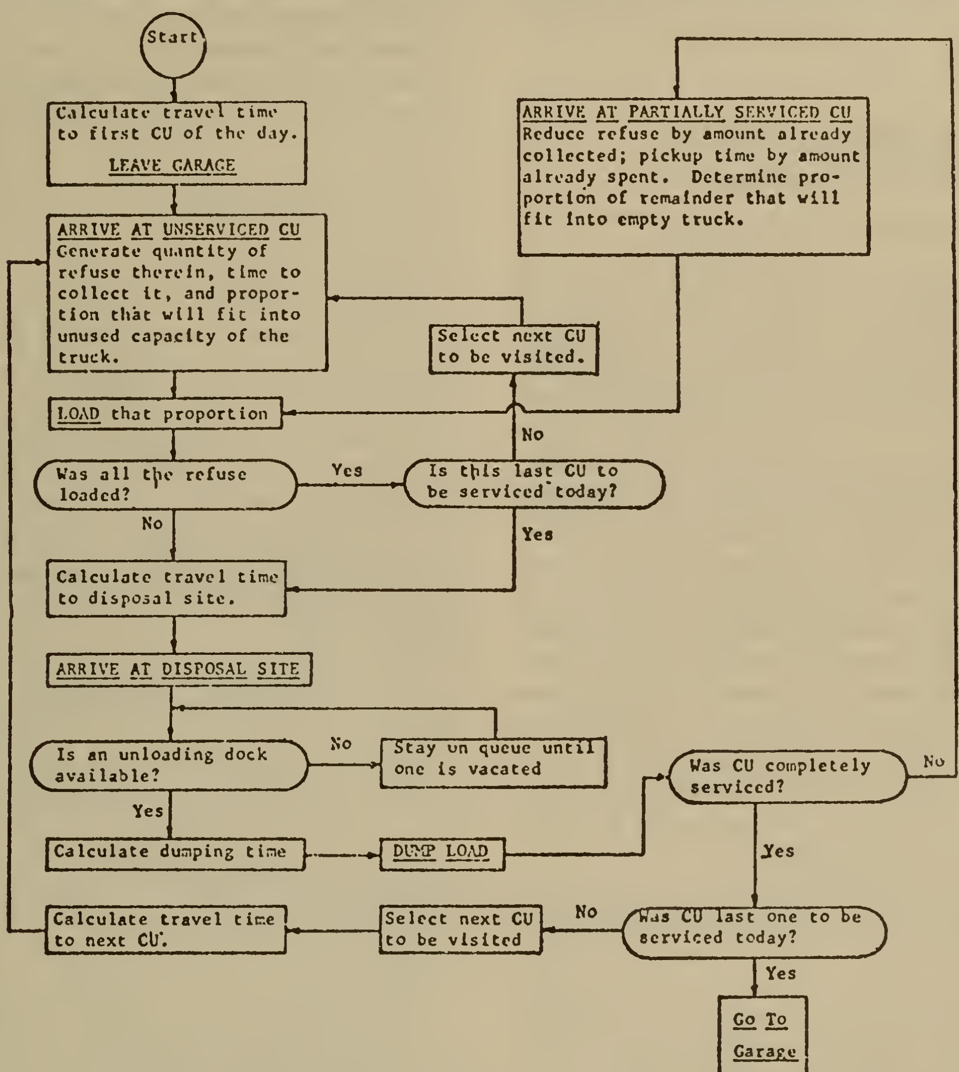
[10] "Mathematical Model for Water Pollution Control Studies," A. S. Goodman and W. E. Dobbins, Journal San. Eng. Div., Proc. ASCE, Paper 5031, SA6, December, 1966.

ing the physical, economic and administrative interrelationships of water pollution control programs. A mathematical model was written for a stretch of river where bordering populations and industries use the flowing water for municipal water supply, disposal of treated sewage, and recreation. Generalized equations and procedures were used to obtain numerical values for the characteristics of importance in the planning, design and operation of water pollution control programs. The principal objective was to define the degree of treatment at a number of sewage treatment plants. For each simulation, 8 quantity and quality characteristics were determined for the water at a number of river sections, 31 physical and economic characteristics were determined for each community, and 12 economic characteristics were determined for the model as a whole.

One method demonstrated for achieving a reasonably satisfactory plan for water-pollution control was to make computer runs for a substantial number of input sets. By successive trials and modifications of the input data, the planner may direct the plans toward specified (or desirable) objectives with respect to water qualities, costs, benefits and other policy considerations. If political, legal or other nonmonetary considerations exert a substantial effect on policies, the desirable or practical plan is not necessarily the least-cost plan and it is likely that the planner can reach a

FIGURE 5

Outline of Model for Refuse Collection Operation for One Truck.



successful plan only through a successive trial and modification procedure.

In another method, the results of each simulation were examined within the computer, which was programmed to automatically make ordered modifications to input data until the results were optimum in terms of least cost or some other specified objective.

In the next pages, we review the work being done in systems analysis as applied to solid wastes. The relatively small number of references cited is ample evidence that the development of this improved approach to design is in an early stage of its development.

Examples of Operations Research In Solid Waste Management

Studies at Northwestern University

A more extensive verbal flowchart than 4, for one-day's operation of a single truck, is shown in Figure 5. This figure is by Quon, Charnes, and Wersan of Northwestern University.[11] Using mathematical simulation and an electronic digital computer, the investigators examined responses of the system to a wide range of values for variables without actual field trials. They advise that the method is not intended to give answers to problems of everyday operation but can describe interactions of variables and can discriminate between variables of primary importance and those of secondary importance. In simulation, they have also been able to consider stochastic variables, in this case daily fluctuations in the quantity of refuse produced, and waiting time at disposal site.

Winnetka, Illinois was the physical model. Invariant parameters for this village were: (1) daily route method of refuse collection, in which each truck is assigned 2 collection units, and there are 2 collections per service per week, (2) two men crews, including driver, (3) fixed locations of garage and disposal site. Variable input parameters which are defined by the designer or obtained from a sample of operation were: (1) mean refuse production in pounds per service per day, (2) standard deviation of refuse production, (3) number of services for each collection unit and internal distance (length of route transversed by truck servicing the collection unit, exclusive of haul distance; the service density of a collection unit depends on the number of services and the internal distance), (4) distance of collection unit to garage and to disposal site, (5) truck capacity, and (6) emperical coefficients related to a computation of pickup time.

For each simulation, information is obtained on time distribution, crew performance and truck utilization. By considering the range of results produced by the simulations, judgments may be made on (1) how to reduce partial truckloads by selection of boundaries of collection area assigned to each truck, (2) when the daily-route method is not as suitable as a more flexible method, (3) truck size as a function of daily refuse production.

The paper indicates that the work in systems analysis at Northwestern University is continuing.

In a discussion of the paper by Betz and Stearns,[12] it is indicated that the Bureau of Sanitation, City of Los Angeles, has used a queuing model for arrival-departure situations, to evaluate the collection fleet reserves required for maintenance purposes.

Studies at Harvard University

Figure 6 shows a hypothetical arrangement of 5 collection units, 2 incinerators, and 5 landfills. Each collection unit can deliver its production to any of the 7 incinerators or landfills. After incineration, the residue is delivered to a landfill. It is desired to minimize the costs over the long run for transportation and processing. For each of five 5-year periods, it is determined what the plan is to be for handling the material from each of the collection units.

The problem of allocating materials to various programs and locations within a specified time period is closely analogous to the pioneering "transportation problem" of operations research in which there are production centers, warehouses, and demand centers, and the aim is to minimize total costs of transportation and distribution. The transportation problem can be solved by a linear programming technique, with an algorithm (step-by-step path for solution), whose program is already available for any sizeable computer.

Other planning situations amenable to operations research solutions, including multiple-units and multiple-periods, can be described which involve collection units, treatment units, and final disposal units. Solutions can aid in decisions as to when and where facilities should be built, when and how they should be enlarged by stages, the routes that should be taken by vehicles, etc. Heuristic methods are used to eliminate very unlikely combinations in order to reduce the size of the

[11] "Simulation and Analyses of a Refuse Collection System," J. E. Quon, A. Charnes, S. J. Wersan, Journal San. Eng. Div., Proc. ASCE, Paper 4491, SA5, October 1965.

[12] See Reference 7.

problem so that it can be solved economically by computer.

An identification of problems amenable to solution by linear and dynamic programming methods is being made by Harrington[13] at the Harvard School of Public Health. Development of models has been largely abstract, although there has been some testing (which, incidentally lead to operating rules that differ from those that might be intuitively established).

Work has been done by another investigator at Harvard on a limited simulation analysis for waste disposal alternatives for the Boston area in connection with the ship-board incineration studies. As mentioned in an earlier part of the report, it is expected that these studies will be published in a few months.

Studies at Johns Hopkins University

A project has recently begun in the Department of Environmental Health to study by means of a systems analysis the potential of transfer stations in the collection system for a portion of Baltimore. The work is being done under a research grant from the Public Health Service. The following description of the study was furnished by M. M. Truitt, Research Associate.[14]

The study proposes the construction of a simulation model of a portion of Balitmore City. Individual trucks will be treated as entities in this simulation, and will be divided into two classes: collection vehicles and transport vehicles. The simulation of collection will be based on actual data concerning the operation of Baltimore City's vehicles; the transport from the transfer station will be simulated using reasonable loading times and travel times from point to point in the city. Simulation trials will be made dividing the city into various numbers of regions, with a transfer point located in each region. Only crude attempts at actual siting of the transfer sites will be made; the important aspect being the number and approximate location of the sites.

The intent is to relate density of transfer stations to density of population, type of area served, collection frequency, etc. Particular attention will be given to expressing results in an efficiency figure which reflects all the costs involved including maintenance, depreciation, land usage, etc., as well as labor.

Throughout the study, the emphasis will be on existing real urban tract with different land-usage units such as row-house, apartment, and residential areas. The basic model will necessarily generalize the configurations of the component tracts and will make some simplifying assumptions in street patterns and haul routes, but the study will be an effort to find generalized information of wide applicability from an investigation of an existing area with realistic data.

Mr. Truitt is in the process of writing the program for an initial model, which will simulate the operation of a transfer station in which the following variables are stochastic:

1. Traffic speeds of collection trucks.
2. Traffic speeds of transport trucks.
3. Service times on transport station scales.
4. Collection rates of collection trucks.
5. Weights per capita of solid waste generated per time period.

The model will allow changes in type trucks, frequency of collection per week, and density of housing units. Field information is being collected currently from the City of Baltimore and its environs for the model use.

Studies by California Dept. of Public Health with Aerojet-General Corporation

A systems approach is being used to study the management of solid wastes on a regional basis for a portion of Fresno County in the San Joaquin Valley in California. Information on this on-going study was furnished by P. A. Rogers[15] of the Cali-

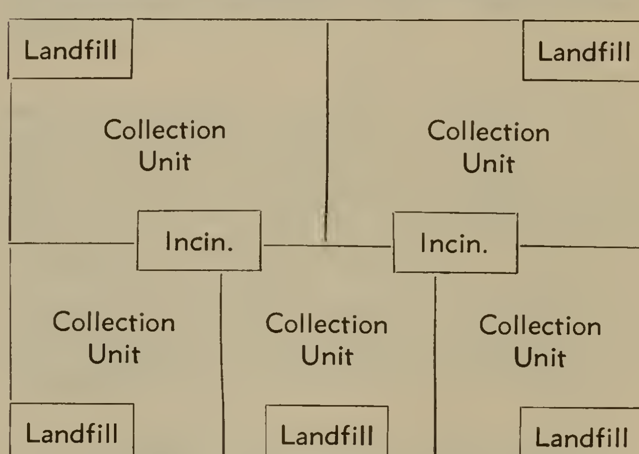
[13]Oral communication from Joseph H. Harrington to A. S. Goodman, June 13, 1967.

[14]Letter to A. S. Goodman, dated April 27, 1967.

[15]Letter to A. S. Goodman dated June 6, 1967 with copy of paper entitled, "A Study to Design an Integrated Solid Wastes Management System," by P. A. Maier and P. A. Rogers, no date.

FIGURE 6

Systems of Collection and Disposal Units



fornia Department of Public Health. It is not clear to us to what extent the study is a "systematic approach" in the traditional sense and to what extent it will involve "operations research" with mathematical applications and the electronic computer. The following discussion is based on material available to the authors. The study is supported in part by a Public Health Service grant; it covers an area of 1200 square miles, about the size of Rhode Island, and involves about 375,000 people in 10 incorporated and 15 unincorporated communities.

The objective of this study is "to investigate, plan and design an area-wide system to handle urban, industrial, and agricultural wastes; and to implement, construct, test, and evaluate the designed areas." In the sense, "construct" is used here, it is probably synonymous with a "paper simulation."

Among the components of the comprehensive investigation, the following appear to be important to a systems analysis: (1) development of standards for both the handling of solid waste products and for the quality of the environment which is to be maintained in the area; (2) identification of the jurisdictional constraints which limit governmental ability to manage solid wastes on a regional basis and to develop an organizational framework by which this may be accomplished; (3) preparation of conceptual designs and specifications for several alternative programs or systems to handle the solid wastes of the Fresno Area satisfactorily; and (4) definition of the criteria and methods to be used in evaluating the alternative systems or combinations of systems on the basis of their economies, efficiencies, and environmental effects.

Of particular interest is the attempt to relate solid wastes disposal with quality of environment. If the intent is to go beyond the requirements for air pollution control and include other public health aesthetic criteria, the results of the study may be quite significant.

The study of a solid waste disposal system for Fresno County is an outgrowth of an impressive study completed by Aerojet-General for the California Department of Public Health about two years ago.[16] This was a first attempt at outlining a systematic approach for solving the overall problem of waste management in California, including the handling of gaseous, liquid, solid and radioactive wastes. Aerojet-General, a leader in applications of systems analysis in defense and space programs, was asked to apply its know-how in this field to assess the suitability of systems analysis and system engineering as tools for solving waste management problems in a political and legal environment. In accordance with this aim, "emphasis was placed on output (environment desired), rather than on disposal of inputs (waste). Present waste handling methods are almost exclusively devoted to coping with increasing waste generation. Little effort is being directed toward designing a waste management system that will produce the air, water, and soil conditions desired by society. For the first time, this study has dealt with all wastes and their impact on health, aesthetic values, and economic and environmental conditions."

We have generally reviewed the report which we understand involved on the order of 100 man-months or more of technical effort. Our judgment is that, whereas a convincing case is made in an overall sense for the merits of systems analysis to handle the waste problems of the land-air-water environmental complex, the presentation with respect to gaseous, liquid and radioactive wastes is more convincing than that for solid wastes. A probable reason for this is that the obvious effects due to movements of pollutants in the air sector of the environment and the movements of quantities of water and pollutants in the surface and ground water sector, which do not respect political boundaries, make air and water good candidates for mathematical systems analysis, whereas the interrelationships involving land disposal are not as amenable to such analysis. Our impression is that much more work needs to be done before the practical validity of solid wastes systems analysis on a grand scale such as that proposed by Aerojet-General can be proven, although we feel that this eventually will be done. With this impression as background, the following principal conclusions of the Aerojet-General report are given:

"1. A total waste management system is characterized by complex interrelationships and by critical geographical, legal, political, and administrative considerations. To optimize a system under these conditions, the proper use of systems analysis and systems engineering is not only advantageous, but is probably the only logical method of attacking this formidable task. System analysis, using defined political institutional, legal, and other constraints with available technologies, permits an optimum system to be designed and, at the same time, allows the

[16] "California Waste Management Study," Report No. 3056, August, 1965, Aerojet-General Corp., Azusa, California.

overall effects of any changes in these constraints to be measured.

2. Having laid the groundwork to utilize system analysis and system engineering, a waste management system can be envisioned that will not only economically dispose of all wastes, but will eliminate detrimental effects on health, will enhance aesthetic elements, and will preserve and increase plant, animal, mineral, and marine resources."

In the study, four levels of solid waste managemen were considered for a region comprising the Sacramento and San Joaquin Valleys and the San Francisco Bay area. These levels, which are stated to follow the system evolution pattern of major aerospace systems, are:

1. An expansion of existing control measures.
2. Application of new control measures that are within the present state of the art.
3. Development and refinement of the present state-of-art control measures to improve and extend them, and to reduce their application costs.
4. Application of advanced control measures to be developed by a full research and development program.

The four levels of control are described in Table 7, entitled "Solid Controls—basic measures instituted to reach the specified level of pollution." Cost estimates were based only on the measures for levels a, b, and c, since the costs for the measure for level d "are so indefinite that they make estimates meaningless."

A conceptual portrayal of a waste management system is shown on Figure 7. This block diagram shows only the essentials, and each of the steps may have a number of alternative methods of solution.

Analog Computers

With analog computers, a system is simulated by means of electric resisters and circuits. Input may be changed by the operator of the simulation, and the output in terms of results or consequences of these changes may be visually shown by electrical means.

The examples of solid wastes systems research outlined above all involve the electronic digital

TABLE 7 — Solid Controls

Basic Measures Instituted to Reach the Specified Level of Pollution

Source	—a— Expanded Existing Control Measures	—b— State-of-the-Art Control Measures	—c— Development Control Measures	—d— Possible Advanced Control Measures
Municipal	70% of solid wastes are collected and put in landfills. The balance is incinerated and dumped.	90% of solid wastes are collected and put in landfills. The bay is not used as landfill site.	Grindable material is separated at household and collected by vehicle which grinds and injects material into sewer line. Remaining collected material is handled as it is now.	Solids ground and flushed down sewer or dropped into automated collector-conveyor systems which transport solids to point where vehicular collectors can transport it by rapid transit to automated processing and separating plants where materials are salvaged and supplied to industry.
Industrial	Industry disposes of own solid wastes.	90% of solid wastes are collected and put in landfills. The bay is not used as a landfill site.	Grindable material is separated at household and collected by vehicle which grinds and injects material into sewer line. Remaining collected material is handled as it is now.	Solids ground and flushed down sewer or dropped into automated collector-conveyor systems which transport solids to point where vehicular collectors can transport it by rapid transit to automated processing and separating plants where materials are salvaged and supplied to industry.
Agricultural	Open burning of stubble and plowing under manure and trimmings.	Stubble is plowed under or burned. Manure is used on farms.	Stubble is plowed under or burned. Manure is used on farms.	Plowed under or transported to automated processing and separating plant.

computer and to our knowledge, no research is underway in the field in which analog computer simulation is contemplated.

In water resource engineering, which can, perhaps, be used as a parallel, the trend has been away from analog computers which historically were used before digital computers in this field (for analyses of pipe networks and hydraulic transient problems). The only really significant area of planning in which the analog computer is believed to have much potential is in flood routing,[17] where the hydraulic interrelationships are extremely complex and where answers must be obtained rapidly to guide those who need to predict flood stages or to operate flood-control works. In other types of planning, design, and operation, digital computer programming is more readily understood and applied by the working engineer and appears to be more economical.

Simulation by Games

ABT Associates, Inc., of Cambridge, has submitted a proposal[18] to the National Science Foundation, to make a simulation for pollution control planning using a technique which they have applied to regional transportation and education planning.

As described in the proposal, the method makes use of an analytical game structured as a human-player simulation of the decision-making process relevant to the public policy issue. The game is a planning tool that educates the participants through an intense problem-oriented process relevant to the public policy issue. The game educates the participants through an exchange of players' individual knowledge; coordinates planning; experimentally tests plans for their relative costs and benefits; and suggests consequences and new alternatives.

The players represent the major governmental, industrial, commercial and consumer viewpoints and interests in a series of independent negotiations. They all begin with a "menu" of technological alternatives with associated costs and availability estimates, and they must end with a widely agreed-on integrated plan.

We are really dealing here then with a method of operations research which, unlike a paper or computer simulation, can in the appropriate circumstances research the intangible aspects of a planning problem, as expressed in the viewpoints and compromises of the participants.

It is not indicated which aspects of pollution will be stressed by ABT, but we surmise that the emphasis will be on air pollution and water pollution. At this time, the effects on air pollution and water pollution are considered to be essentially technological problems for solid wastes disposal, and these problems cannot be resolved by compromise among government decision-makers and public and private interests.

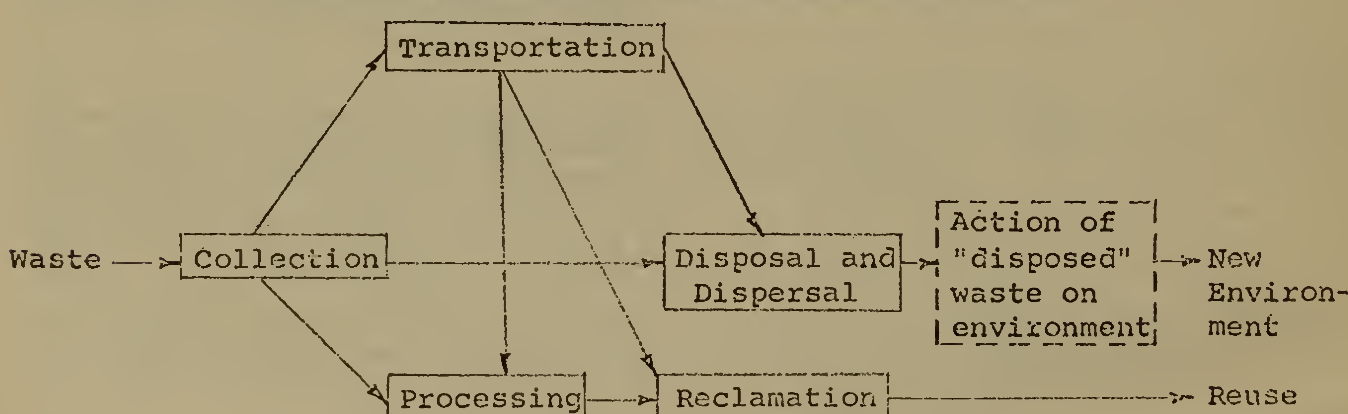
It would be of substantial interest to us, however, to observe as a result of such a study the extent to which the various interests understand and react to the technical aspects of a municipal public works undertaking, and what their views are on regional versus local management. We,

[17] "Analog Models for Stream Hydrology," J. A. Harder, "Water Research," A. V. Kneese and S. C. Smith, ed., Johns Hopkins, 1966.

[18] Proposal for "Design, Development, and Demonstration of Pollution Control Planning Simulation," by ABT Associates, May 1, 1967.

FIGURE 7

Conceptual Flowchart of Waste Management System



therefore, recommend that the ABT proposal be favorably acted upon.

Conclusions

On the basis of our evaluation of the current status and potential of systems analysis, we offer the following comments:

1. All plans for solids wastes collection, treatment and final disposal for individual communities and for regions should be developed by a "systematic approach." This is desirable for the individual community, and essential for the region.

2. Systems analysis for solid wastes management, involving mathematical methods and the electronic digital computer, are in an "initial" stage of development. A family of situations where such techniques have been evaluated may be available within the next few years. Based upon the advantages which have been shown for such methods in other engineering fields in a more mature state of development, a good payoff may be expected in solid wastes management when the techniques are regularly used and properly applied.

3. All studies of solid wastes management should consider the water and air interfaces. Relationships involving the air-water-land complex should be indicated, using quantitative measures to describe effects to the greatest extent possible. Our capability to do this should improve along with the development of systems analysis.

4. It is desirable for the engineer or planner of solid wastes programs to be familiar with the techniques of systems analysis, in order to recognize situations when such techniques would be valuable. In recruiting personnel for their expanded roles in waste management leadership, agencies such as the Department of Public Health should seek to obtain engineers and planners with at least some qualification in systems analysis; at the present time, mathematical systems analysis and computer programming are not utilized as tools by the DPH.

5. Until or unless capability in systems analysis is available in the State agencies, consultants should be retained to make appropriate special technical studies and to assist the state agencies in their functions of review of community and regional plans.

Chapter VII

CURRENT RESEARCH

Introduction

This section of the report considers the research which is currently in progress in the area of solid wastes collection and disposal. These projects are in various stages of development and their impact on planning will be different for almost each community. Research by its very nature does not always produce positive results and the public must not expect a one hundred percent return on its investment. If all the answers were known about a technique, there would be no need to conduct a research project. The fear of failure has made public officials justifiably reluctant to accept innovation and new methods for their communities. This attitude has made it necessary for consulting engineers to be conservative and rely on tried and tested methods. In general, regulatory agencies throughout the nation have also been reluctant to approve innovations, expressing concern for a waste of the taxpayer's money which would leave them open to public criticism. The aforementioned problems are in part responsible for the retarded progress in solid waste treatment, as well as the other environmental pollution activities, such as wastewater treatment and air pollution control.

Who should be supporting the research effort in the pollution area? The three groups of people involved with the problem include: State and Federal agencies, consulting engineers, and equipment manufacturers. The latter two groups have not been able to support the required research. Low profit margins for consulting engineers prevent them from investing sufficient funds in research. For a number of reasons the equipment industry has also been reluctant to make the required research contribution. This leaves the State and Federal government to stand virtually alone in this research area. In the past, some few states and local governments have made research contributions on a limited scale with varying degrees of success. Today more significant work is being carried on by states alone and in some cases in conjunction with the Federal government. Until recently (1965), the Federal activity in solid waste studies was nil. The Solid Waste Disposal Act was passed on October 20, 1965 and is described in detail in Chapter II. This act makes provisions for planning, development and conduct of solid waste programs, including research and development programs.

We obtained listings of the Federally supported research grants, demonstration grants, and contracts from the officials of the solid waste program in Washington. After a review of the active projects, letters requesting additional information were sent to those whose studies would have an impact on solid waste planning in the Commonwealth. The response was approximately 70 percent, but the amount of detail was rather disappointing. In almost every case, the reason was, that the project was just getting underway, and all that was available was the "hoped for" results. We, therefore, will in this section of the report present the types of projects under investigation in each of several categories. The purpose of this discussion is to give the reader some perspective as to the direction of the national research effort. It is not the intent to convey the idea that these early studies can be applied immediately, but rather to give an insight into what the future holds. This knowledge is critical for those involved in solid waste planning since it is standard practice to consider at least 20 years into the future. The exact details of the results of these projects will be appearing in technical journals and governmental publications. These results must then be seized by engineering planners and regulatory agencies and be implemented to realize the maximum benefit in terms of public health and economics.

Management Studies

A new concept in waste management[1] is in the developmental stage in California. The plan was evolved from a study by the Aerojet General Corp.[2] on the application of systems analysis to

[1] "The California Integrated Solid Waste Management Project-Progress Report," State of California, Dept. of Public Health, Bureau of Vector Control, May 16, 1967.

[2] "California Waste Management Study," A Report to the State of California Department of Public Health, Aerojet-General Corp., Report No. 3056, Azusa, California, 1965.

waste problems. The systems approach is described in Chapter VI. In addition to waste management, the State is expected to let contracts in systems analysis application to other areas, such as crime and transportation. The waste pilot study considers all aspects of the environment as a single system with subsystems of air, water and land. Using the system which will be developed, it will be possible to determine the cost for any level of environmental conditions desired, taking into account all the interrelationships which exist. Traditionally, disposal activities have been contained by political boundaries. This is where the California plan differs in an effort to lower the per capita costs. The plan calls for boundaries to be set by such factors as common topography, meteorological conditions, waste composition, etc. The PERT (Program Evaluation Review Technique) schedule for the pilot study calls for it to be completed in June, 1969. The results will include a complete state wide waste survey with predictions of future quantities, a management structure, a recommended time table for accomplishments, recommended assistance programs, setting of standards, and required legislation to implement the entire program.

The waste management program will have a State Technical Advisory Committee to recommend policy and review progress through the Department of Public Health. The advisory committee will be composed of representatives of state and local governments, health, planning, finance, agriculture, academic disciplines and private industry. The goal of the program is stated as: "The basic need at this point is a comprehensive, projected plan to bring together state and local governments along with private industry as partners in a coordinated waste management program for the optimum benefit of all the people of California." [3]

We believe that the California plan of waste management has some fine new dynamic approaches which should be considered for the Commonwealth. We recommend a detailed study of the techniques suggested with a consideration for possible application perhaps to the New England area as a whole.

Collection and Transportation Research

Several communities in the nation are, with the aid of a Federal grant, planning to apply a systems analysis concept to their local collection system in an effort to design the most efficient system. Demonstration type studies of this nature are in progress in San Jose, California and Raleigh, North Carolina. Harvard is using systems for the costs associated with collection as part of its ship incineration project. It is expected that methodologies developed from these studies will lead to a more refined computer model with subsequent increased use in other communities.

The City of Raleigh, North Carolina has been conducting several studies on its waste collection system. North Carolina State University students, as part of a course in industrial engineering, made a work-measurement study of the city's garbage collection.[4] The study included an evaluation of the use of train type garbage collection which indicated, for certain types of population densities, the use of this system would realize a cost reduction in collection. Continued use of standard work measurement type techniques to all solid waste collection systems should result in the most economical routes and manpower use. The type of data gathered from such a study is required for the application of computer simulation models since its usefulness is controlled by the input data.

Researchers at the University of Pennsylvania are working under a Federal grant to study the feasibility of a solid waste pipeline. They cite the unsightly, inconvenient and unhealthy aspects of collection in addition to overtaxing of transportation arteries as reason for the need of a completely new system. The proposal calls for some type of home grinding unit and a reliable pipeline to any one of many available types of final disposal areas. There are many problems which must be investigated, including the use of the already overtaxed water resources. They plan to develop an economic comparison for a section of Philadelphia. where the existing solid waste collection costs are well established. This work is an interesting alternative to today's collection methods, but it is expected that several years will be required to work out the technical problems involved.

In the total research effort, only a small part is devoted to collection systems but, in most cases, this represents well over 50 percent of the per ton cost. We would encourage any community desirous of making unique studies of their collection process or any other phase of the solid waste problems to make application to the U. S. Public Health Service for part or all of the costs involved.

[3]Rogers, P. A., "The Development of a Comprehensive Solid Waste Management Plan for California—A Preliminary Report," California Vector Views, California Dept. of Public Health, Vol. 13, No. 12, December, 1966.

[4]Personal communication, Warren J. Mann, Director, Department of Public Works, City of Raleigh, N. C., July 10, 1967.

Sanitary Landfill Research

The investigations underway concerning sanitary landfills fall into several general categories. Basic studies include determining the biochemical reactions involved and the factors affecting the rate of stabilization in an effort to predict the suitability of a fill for future use. Another major area of study is the ground water pollution associated with landfills.

There is an active research grant at the University of Southern California, studying the mechanics of landfills. They have made comparisons of aerobic and anaerobic types of fills and investigated other factors such as moisture content and its effect on the rate of stabilization. An outgrowth of these initial studies is a demonstration project for the City of Santa Clara, California, using accelerated stabilization[5] for a landfill operation. The initial effort will be to make an evaluation of an aerobic and anaerobic fill using the city's refuse. Aerobic conditions are maintained by using an aeration and irrigation piping system. The second phase, assuming success in the first, will be the construction of a full scale aerobic landfill with which a complete cost estimate can be prepared. The proposal calls for the oxidized refuse to be used for such projects as embankments for roadways and parking areas. This project is scheduled for completion by June, 1969.

Drexel Institute of Technology is the recipient of a solid waste grant for a study entitled, "Pollution of Subsurface Water by Sanitary Landfill." [6] This is an extremely important area since it involves the air-water-land complex. The study has the following long range objectives: (1) to predict the movements of contaminants in subsurface water, (2) to investigate methods to reduce or stop the flow of contaminants, and (3) to develop hydrologic, geologic and soil criteria for landfill site selection.

We feel that the results of these and other landfill research projects will benefit solid waste engineering planners by providing guidelines for site selection. Although planners are aware of possible ground water pollution, today, there is no method of rationally determining to what extent it is a problem. It would be desirable to operate on a pilot scale some techniques of accelerated landfills for the determination of the effect of the New England climatic conditions.

[5]Personal communication, Ralph Stone, Ralph Stone & Co., Inc. Engineers, Los Angeles, California, June 21, 1967.

[6]Personal communication, Prof. Irwin Remson, Drexel Institute of Technology, Philadelphia, Pennsylvania, June 12, 1967.

Incineration Research and Demonstration Projects

There are a number of active research and demonstration grants for incineration which are supported totally or in part by the U. S. Public Health Service.

San Jose, California, in addition to applying systems analysis to its collection system, is demonstrating a new type incinerator. The Sira Disposal System to be used depends on extensive refuse preparation such as grinding, shredding and separation of non-combustibles prior to incineration. The expected results of the fine particle burning include a reduction in air pollution by use of minimum amounts of excess air combined with lower construction and operating costs.

A demonstration and research incinerator has been constructed in The District of Columbia for the purpose of conducting a series of experiments. The studies include: air pollution control, heat recovery, metal recovery, control laboratory, chipper installation, and compression press. The results of this work and other projects they plan to undertake in the future should have a positive impact on incinerator design throughout the nation. The results of these studies will be available shortly and can be obtained from the USPHS, Solid Waste Program office.

Faced with the problem of varying sizes and types of input material, Norman Wagner of Stamford, Connecticut has designed a multipurpose incinerator.[7] He expects to start construction of the facility in October, 1967, which will be supported in part by the USPHS. The design calls for special ignition chambers prior to introduction to the combustion chamber. The unit will have the capability of incinerating such special wastes as oversized burnables, inflammable liquid wastes, combustibles on auto bodies, and dead animals. This project has the distinct advantage of being able to treat the many waste items which cannot be handled by the conventional incinerator. The proposal calls for the inclusion of sophisticated air pollution equipment. The results of this project could be quite helpful in solving the problems of many communities. Results should be forthcoming in the next few years.

The Federal government is financing a study on the recreational use of waste heat from incinerators in Hackensack, New Jersey. The proposal is for the installation of an incinerator in a park development plan. The purpose of this location is

[7]Personal communication, Norman Wagner, Supervisor of Sanitation, City of Stanford, Connecticut, June 24, 1967.

to prove that it can be operated without producing any nuisance or other problems with the surrounding recreational activity. The waste heat will be used for the powering of a large blower fan to reduce the stack requirements and to operate an ice skating rink and an indoor swimming pool. The project started in June, 1966 and is expected to be completed in May, 1969. This project has direct implications for the Commonwealth since it has numerous skating-swimming recreational complexes, some of which might be suitable sites for incinerator construction. New proposals for these complex constructions should consider the inclusion of a solid waste disposal facility. A new park could be developed in an unsuitable area by landfilling with the incinerator residue.

General Research Activity

Federal monies continue to support some composting projects in an effort to prove once and for all the operating expenses and the practicality of this type of disposal. The most recent project[8] is for a medium-size range (50,000-100,000) population in Gainesville, Florida. The system to be demonstrated is a high-rate, mechanical refuse composting plant designed by Metropolitan Waste Conversion Corp. The primary objective is to determine the reliability, suitability, sanitation and economic feasibility of such an installation. They will also attempt to use this facility to provide final disposal of sewage sludge. A side benefit will be the use of the plant for teaching and research for the University of Florida. An installation of this type should provide useful information in the future, which can be used in an economic comparison of several disposal facilities.

The University of California, Berkeley, has started some advanced treatment research, which includes wet oxidation, anaerobic digestion and biological fractionation. The status is currently one of establishing laboratory techniques for the studies. Results which could be translated into actual installations are several years in the future.

Oregon State University has been awarded a grant to study chemical transformation of solid waste in an effort to provide an alternative to incineration and dumping. The refuse composition is known to contain certain chemical groups which undergo standard reactions. This investigation will attempt to determine the proper conditions and catalysts for the desired reactions. As with many of the other research projects this is still in the early laboratory stages, and it will be several years before field type installations could be made.

[8] Personal communication, Victor Brown, President, Metropolitan Waste Conversion Corp., Wheaton, Illinois, June 21, 1967.